

Final Report

for

**THE ESTABLISHMENT AND OPERATION  
OF THE  
APPAREL MANUFACTURING TECHNOLOGY  
CENTER**

to

U.S. Defense Logistics Agency  
Cameron Station  
Alexandria VA

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## TABLE OF CONTENTS

	<i>Page</i>
EXECUTIVE SUMMARY	1
1. INTRODUCTION	5
2. PROGRAM OBJECTIVES	8
2.1 <i>Background</i>	8
2.2 <i>Designing, Equipping and Operating an Advanced             Apparel Manufacturing Technology Demonstration Facility</i>	10
2.3 <i>Establishing an Apparel Industry Coalition</i>	17
2.4 <i>Demonstrating Non-Traditional Capital Investment Criteria</i>	17
2.5 <i>Operating an Apparel Manufacturing Technology             Dissemination Service</i>	19
2.6 <i>Conducting Applied Research</i>	22
2.7 <i>Student Involvement in AMTC</i>	27
3. RESULTS AND BENEFITS ACHIEVED	27
3.1 <i>Operation of AMTC Demonstration Facility</i>	28
3.2 <i>Demonstration of Non-Traditional Capital Investment Criteria</i>	33
3.3 <i>Operation of an Apparel Manufacturing Technology             Dissemination Service</i>	34
3.4 <i>Research Programs</i>	39
3.5 <i>AMTC's Teaching Factory Initiative</i>	44
4. LESSONS LEARNED	46
5. APPENDICES	49
APPENDIX A - AMTC Advisory Committee and Industry Coalition members	
APPENDIX B - Samples of <i>AMTC Quarterly</i> and <i>AMTC Technical Tips</i>	
APPENDIX C - Summaries of AMTC Research Projects	
APPENDIX D - AMTC Research Presentations and Publications	
APPENDIX E - Photographic Record of AMTC	
APPENDIX F - Initial AMTC Pilot Plant Design	
APPENDIX G - Grants of Equipment and Services to AMTC	

### EXECUTIVE SUMMARY

Apparel Manufacturing Technology Center (AMTC) is a research and technology transfer program oriented toward the specific needs of the apparel industry. It has been in existence since 1987 with the core funding provided by the U. S. Department of Defense. Since 1987, DOD has invested \$9.2 million in AMTC. AMTC's role is vital as over 900,000 U.S. manufacturing jobs are at stake in the world market of apparel production.

#### *Resources Combined With DOD Funding:*

- \$700,000 provided by the Woodruff Foundation to start-up the AMTC Teaching Factory at Goodwill Industries of Atlanta.
- \$500,000 (\$250,000 from the Governor's office and \$250,000 from industry) for expansion of the pilot plant facility at Southern Tech.
- \$2.9 million per year DOD set aside, nonprofit apparel production contract (Goodwill Industries of Atlanta).
- \$500,000 per year equipment grant (Fiscal Year 1994, 1995, 1996) awarded by the state.
- \$2.2 million in equipment grants and consignments from industry.
- \$2.25 million building grant (50% from the state and 50% from industry in 1987) to construct facility housing the pilot plant laboratory at Southern Tech.

#### *Research and Development:*

A broad range of applications research and development programs have been completed and are under way at AMTC. The AMTC research and development endeavors range from equipment automation and human resource job enrichment to reduced time-to-market and information technology projects.



*Technology Transfer:*

AMTC technology transfer initiatives are provided by an array of endeavors including:

- In-plant assistance.
- Seminars and workshops.
- Pilot plant scale demonstrations of advanced manufacturing technology and management practices.
- Pilot plant industry prototyping and feasibility analysis of equipment, processes, and practices.
- Teaching factory (operational in December '94) to develop and disseminate techniques for 1) enlarging the potential worker applicant pool via assimilating intercity poor into the manufacturing environment and assimilating mentally and physically challenged into the manufacturing environment, and 2) Introducing advanced worker management practices including compensation programs, team concepts, ergonomics, etc. to demonstrate job enrichment and lower turnover.
- Graduating 25 apparel engineering technologists per year (by the only certified ABET program in the country) with direct hands-on advanced manufacturing experience.

*AMTC's Pilot Plant:*

Located on the campus of Southern Tech, it augments the only ABET accredited apparel engineering program in the country. The pilot plant is composed of 6,000 square feet of laboratory and computer space. The space is occupied with \$2.3 million in advanced apparel manufacturing equipment operated largely by students. It provides a work center for students to conduct academic exercises/labs. Also, it provides industry a platform to evaluate/test new concepts, equipment, and systems. It also provides a launch point for promoting advanced

manufacturing techniques and equipment to industry. The facility is equipped with distance learning capability as well as an 80 person lecture room and four smaller classrooms for seminars and workshops to augment hands-on demonstrations. The facility was constructed in-part with industry dollars. The facility opened in 1988.

*AMTC'S "Teaching Factory" Initiative*

AMTC's Teaching Factory is established as a partnership effort with Goodwill Industries of Atlanta. Goodwill Industries of Atlanta will operate a full time utility trouser apparel factory in conjunction with AMTC's pilot facility at Southern Tech.

AMTC Accomplishments:

- Conducted 176 industry technical assistance projects.
- Conducted 57 workshops and seminars with 1088 attendees.
- Conducted 197 pilot plant advanced technology equipment/process demonstrations, hosting 16,646 attendees.
- Attained ~\$10.3 million in federal dollars invested in the program.
- Leveraged federal dollars to attain \$4.23 million in cost share from various sources.
- Employed 74 students (who entered industry with this unique experience) in advanced manufacturing technology operations.
- Produced 3,392 student/lab projects, with many addressing a specific industry problem.
- Facilitated in the installation of an modern apparel plant (83 operators) in Atlanta Federal Prison.
- Facilitated in the installation of Terry Manufacturing (75 operators in 1995) in south Fulton County.

- Facilitated the buyout (and capital infusion) of a troubled apparel customizing operation (employment 17) in Atlanta.
- Facilitating the installation of a sewing plant (new employment ~ 95) in Rabun County - start-up in 1995.
- Facilitated in the enlargement of a sewing plant (new employment 135) in Miami Florida to produce both civilian and DOD products.

AMTC is a model program of leveraging a variety of resources and organizations for the common good of this important industry.

### **1. Introduction**

The Defense Logistics Agency (DLA), the primary procurement organization for the U.S. Department of Defense, solicited universities to propose centers for the Advanced Apparel Manufacturing Technology Demonstration (AAMTD) program. These centers were to conduct and to stimulate the transfer of advanced manufacturing technology to the U.S. apparel manufacturing industry, with particular emphasis on modernizing firms which contract with DLA. On August 20, 1987, the Georgia Institute of Technology-Georgia Tech Research Corporation, in collaboration with the Southern College of Technology as a subcontractor, was awarded DLA contract DLA900-87-D-0018 for establishing and operating an Apparel Manufacturing Technology Center (AMTC).

The principal goals of the AMTC are to:

- 1) Establish and operate a facility to demonstrate advanced apparel manufacturing technology.
- 2) Develop new methods for evaluating capital investments in the U.S. apparel industry.
- 3) Establish and operate a service to disseminate information on new technologies and their application to the U.S. apparel industry.
- 4) Conduct short-term research projects for developing new technology for improving

manufacturing productivity and competitiveness in the U.S. apparel industry.

- 5) Establish a coalition of apparel industry members to advise and support the AMTC.

The technology demonstration facility was established at the W. Clair Harris Center of Excellence for Textiles and Apparel Technology, a new 22,000 square foot lab and classroom facility on the Southern Tech campus. A picture record of the facility is contained in Appendix E. New technology for use in the demonstration facility was donated or consigned by equipment vendors, and the estimated value of this equipment and software over the seven-year reporting period is \$3.2 million. DLA funds were not used for equipping the demonstration facility.

An extensive evaluation of methods used for assessing the value of investment in new technology in the U.S. apparel industry was conducted by Georgia Tech economists. Using the results of this work, new techniques for economic evaluation of capital investment were developed into a software tool called COMPASS and are being disseminated to apparel manufacturers.

The center was dedicated in September, 1988, and 197 formal technology demonstrations (hosting 16,646 attendees) have been conducted at the center since that time. Diverse technical topics have been addressed in-depth through workshops conducted by AMTC in conjunction with the manufacturing demonstrations. These workshops and demonstrations are key elements in disseminating knowledge of new technology to apparel firms because they offer opportunities for one-on-one interactions between industry decision-makers and AMTC staff and researchers. In support of these activities, AMTC has published quarterly 4-page newsletters, technical briefs, and special mailings on specific aspects of advanced apparel technology. These widely distributed publications were designed to keep the reader up to date on AMTC research, activities and events.

In February, 1990, DLA funded a new AMTC service which offers in-plant consultations by AMTC staff. These projects offer a broader dimension for transferring knowledge of new technology to the industry in a valuable one-on-one "house call" between industry managers and knowledgeable AMTC staff. The maturity of the AMTC program and the expertise developed by

the staff working closely with manufacturers, vendors and researchers, represent unique capabilities for assisting apparel firms to solve technical and management problems.

While the demonstration center and technology dissemination services focus on transferring off-the-shelf technology, the AMTC research program is aimed at developing new technological solutions to problems facing the U.S. apparel industry. Thirteen short-term projects have been initiated in the seven-year reporting period, and four of these are ongoing. The research projects are addressing issues such as:

- Computer modeling of generic apparel manufacturing operations.
- Developing an automated system to attach Battle Dress Uniform cargo pockets.
- Developing a new tool for economic justification of capital investments.
- Improving workstation supervision through ergonomics.
- Evaluating modular manufacturing (flexible work groups) techniques.
- Improving marker making with computer technology.
- Improving detection of fabric and sewing defects by using advanced technology.
- Improving cut order planning with computer technology.

Appendix C contains a summary of each of the research projects. Research conducted by AMTC researchers is in collaboration with participating apparel firms. The research findings are widely disseminated through public demonstrations, presentations, and publications.

In order to assure apparel industry support and participation in the AMTC, an industry coalition was formed, which currently consists of over 230 industry and government officials. The coalition serves as an initial launch platform for AMTC technology to industry. An industry Advisory Committee, which currently has 17 members, was also formed to act as an industry advisory board for AMTC. The committee provides general industry representation for planning

AMTC activities.

The following findings are based on the results of operating the AMTC since August, 1987:

- The federal government (e.g., DLA) can be a significant catalyst in causing industry managers and university staff to join forces for solving prevailing technological problems.
- Innovative firms will be the strongest supporters of efforts like AMTC, but these firms can also lead by example (being mentors for) the smaller, less innovative firms who may be the actual targets of greatest need for methods and technology.
- Technology vendors readily participate in a program like AMTC with donation or consignment of equipment and in-kind support, if it will showcase their products. However, substantial equipment funds are needed to augment consignments.
- Workshops and face-to-face interactions (e.g., technology demonstrations) between AMTC staff and industry representatives is a very effective way to disseminate and exchange information on new technologies.
- U.S. industry leaders are seeking new technology which can help them be more competitive. However, when making a decision to invest, the perceived risk to the firm must be low, relative to the complexity and cost of the technology. A center such as AMTC can help minimize this risk and uncertainty.
- At this stage, continued DLA funding is critical to the viability of the AMTC. It is unrealistic to expect significant support from a fragmented industry which is generally suffering economic distress. Apparel manufacturers have not traditionally invested in R&D.
- The AMTC experience has indicated that the ranking of technology transfer activities, with respect to relative effectiveness is as follows:
  1. Mentor-Protege interaction between successful industry innovators and less technically diverse manufacturers is the most successful technology transfer tool.
  2. In-plant, problem-solving consultations between knowledgeable staff and apparel managers is second in effectiveness.
  3. Workshops and face-to-face interactions during technology demonstrations, supplemented by quality publications is third.

4. Research projects and the dissemination of findings, is also valuable, especially for launching leading edge technology to industry innovators.

## **2. PROGRAM OBJECTIVES**

### **2.1 Background**

The apparel manufacturing industry in the United States has been on the decline for the past 10-20 years relative to total revenues (sales) in real dollars, percent share of the domestic market, and total sector employment. The height of apparel manufacturing employment occurred with approximately 2.1 million operator jobs in 1969. Today, slightly over 900,000 operators comprise the industry. However, the output in real dollars has remained constant. Industry analysts have pointed to increased competition from foreign manufacturers as the cause of this decline, with these competitors bringing lower-cost products to the expanding U.S. market because of significantly lower labor costs. Labor costs compose about 50 percent of the cost of goods sold. In order to offset this labor cost disadvantage, U.S. firms must adopt, new advanced manufacturing technology and management techniques. This strategy must focus on maintaining leadership in apparel quality and time to market, with added emphasis on product variation and small production lots.

How did the U.S. apparel industry arrive at this state of declining competitiveness? Like many traditional U.S. industries, apparel firms have historically operated in isolation from the changes being wrought by the rise of the global marketplace. At the same time, foreign competitors in countries which were intent on industrial development in the period after World War II have focused on *building* an industry base. Traditional industries with high labor content, such as apparel, were prime candidates for growth and exports. Also, once foreign competitors target the apparel industry, importing to the huge and lucrative U.S. market was an obvious marketing strategy. Thus, the U.S. apparel industry was operating as it had been for many years, while the foreign competition was aggressively targeting markets which had historically been dominated by domestic producers. The same phenomenon in the apparel industry has occurred in all developed nations. In Europe, Portugal and Ireland have become aggressive apparel exporters.

In the Far East, China, Sri Lanka, Bangladesh, and Thailand are experiencing rapid growth in plant capacity. In the West, the Caribbean basin, Mexico, and South America mirror this growth.

A corollary to this situation is found in that portion of the U.S. apparel market represented by apparel purchases made by the U.S. government, which is comprised primarily of military garment purchases. In the military apparel market segment, contractors who manufacture for the U.S. Department of Defense (DOD) continue to be isolated from many of the global market forces with which civilian firms have had to cope. This is because DOD contractors usually rely solely on government purchases for their business. This, in conjunction with traditional lowest bid contract awards system, often results in federal apparel contractors operating with frequently outmoded methods and technologies because production costs due to inefficiency can be passed to the government. Isolation from the market forces which are stimulating the civilian market has the effect of stifling innovation in government contractor facilities and, as a result, these plants are disadvantaged in their ability to compete in markets other than the ones they currently serve. This problem is now exasperated for traditional government contractors with the current trend toward best value government contract awards and downsizing of the military.

The U.S. Defense Logistics Agency (DLA) is the main procurement organization for all branches of the military services. The Defense Personnel Support Center (DPSC) of DLA is responsible for procuring military apparel through contracts with U.S. manufacturing firms. In 1986, DLA issued a Request for Proposals (RFP) for the establishment of university-based Advanced Apparel Manufacturing Technology Demonstration (AAMTD) centers. These centers were required to create sites where apparel manufacturers could learn of advanced technology in order to both stimulate technology investments and further identify industry needs for new technology.

The Georgia Tech Research Corporation submitted a proposal under this RFP and in August, 1987, was awarded a contract from DLA to establish and operate an Apparel Manufacturing Technology Center (AMTC) in Atlanta, Georgia.



## **2.2 Designing, Equipping and Operating an Advanced Apparel Manufacturing Technology Demonstration Facility**

Federal programs oriented toward transferring advanced technology to important sectors of the economy have been operated for over a century. Agricultural technology was showcased at demonstration farm sites by Agricultural Experiment Stations funded by the U.S. Department of Agriculture at land grant universities as early as the 1880's. By 1920, the Cooperative Extension Service was created to provide an agricultural technology transfer system for reaching the farmer directly via one on one mentoring and group technology transfer methods. Since then, federal agencies have supported demonstrations in technologies as diverse as nuclear power reactors and personal transportation systems.

The U.S. Department of Defense (DOD) has been a leading federal agency in developing and transferring advanced technology to industry through several programs, including the Manufacturing Technology (MANTECH) program, the Technology Modernization (TECHMOD) program, computed aided logistics support program (CALS), and the Industrial Modernization Incentive Program (IMIP). However, projects conducted by these programs typically involved a single DOD contractor, with technology transfer to other contractors after the project is completed.

The AAMTD program was developed to focus on the technology needs of a critical industry sector rather than on a single firm. This approach provides a broad-based technology transfer program which is flexible and responsive to the immediate technology priorities of the apparel manufacturing industry. To assure close coupling between the AMTC and the apparel industry, DLA support of the AMTC was contingent on the following support criteria:

- 1) The contractor must cost-share 33% of the total cost of establishing and operating the technology transfer center.
- 2) DLA funds could not be used to purchase equipment for the demonstration facility.
- 3) An industry advisory coalition of apparel firm executives was required.
- 4) The AAMTD is to become self-sufficient in funding by the end of program year.

Establishing a state-of-the-art microfactory as a technology demonstration facility was a high priority for each AAMTD center. This facility would also be used for training, information dissemination, technology development, and, most importantly, creating a strong coalition of manufacturers, equipment vendors and university faculty.

The following sections describe the development of the demonstration facility and related AMTC activities.

**2.2.1 Fabric and Garment Selection for Manufacturing:** Initial decisions of which garment to manufacture and what fabric to use in the demonstration facility were important ones in order for the demonstration facility to be credible and successful. The Navy denim workpants were initially selected, based on discussions with DPSC and the following rationale:

- 1) Heavy fabric (i.e., denim) is stiffer and therefore easier to handle in automated processes.
- 2) Trousers are less automated due to the long seams, making trouser production more vulnerable to low wage foreign producers.
- 3) Jeans, which are very similar to workpants in construction and manufacture, are the highest volume garment produced in the U.S.
- 4) The first and second largest jeans manufacturers in the U.S. (The Lee Company and Levi Strauss and Company, respectively) actively support Georgia Tech.
- 5) The technology developed for the workpants is generally applicable to the manufacture of all trousers and some shirts, especially battle dress items.

After successful operations in denim products, AMTC converted its pilot plant to Battle Dress Uniform (BDU) trousers (Type 4) in 1990 to apply lessons learned to this product. BDU trousers are one of the highest volume apparel items consumed by DOD with over two million pairs purchased annually.

**2.2.2 Equipment Selection and Acquisition:** During the process of developing the proposal in 1986, Georgia Tech and Southern Tech faculty members contacted a number of firms that manufacture advanced technology equipment for apparel manufacturing and solicited their interest in participating in the AMTC. Based on the strength of the reputation of several of these faculty with the apparel industry, letters of interest from a number of vendors were received to enable the submittal of the proposal. Table 2.1 is a list of those firms contacted and those who sent letters.

**Table 2.1**  
**Apparel Equipment Vendors Supporting the AMTC Proposal**

1.	SES Systems, Inc.
2.	Lectra Systems, Inc.
3.	Eastman Automated Systems, Inc.
4.	Laser CAM Systems, Inc.
5.	Juki Systems of America, Inc.
6.	Sunbrand, Div. of Wilcox and Gibbs, Inc.
7.	Cutters Exchange, Inc.
8.	Eton Systems, Inc.
9.	Jet Sew, Div. of Cluett
10.	Pfaff-Pegasus of USA, Inc.
11.	Microdynamics, Inc.
12.	Gerber Garment Technology, Inc.
13.	Lewis Sales, Inc.

After the award was made, efforts began in earnest to secure equipment either on consignment or as an outright donation to the AMTC. Typically, a firm manufacturing or marketing equipment or systems which was planned for inclusion in the AMTC was contacted and visited. In some cases, for example with the selection of a unit production system, several vendors were solicited and asked for formal proposals explicitly stating the terms of their participation as equipment donors. Then these proposals were evaluated to determine the best fit with the AMTC plans and resources.

Commitments for equipment, software, and services worth over \$3.2 million were eventually secured. This amount more than covered the \$666,666 of initial cost-sharing required of Georgia Tech by the contract. A complete listing of the firms who initially donated equipment and/or services to the AMTC is presented in Table 2.2.

Table 2.2

**Firms Initially Donating/Consigning Equipment or Materials to the AMTC**

<b>Firm</b>	<b>Amount</b>
Apparel Computer Systems	\$101,655
Astechnologies	1,000
Atlanta Attachments	20,658
Brother	44,000
Byte Systems	10,000
Coats and Clark, Inc.	1,160
Durkopp America	190,000
EFGA	2,000
Gerber Garment Technology, Inc.	450,000
H.D. Lee	2,100
Hewlett-Packard	623,000
Juki Industries of America	23,733
Kurt Salmon and Associates, Inc.	25,000
Methods Workshop, Inc.	28,000
Mitsubishi Electric Sales of America	37,242
Mr. Engineer, Inc.	5,000
Pfaff-Pegasus of U.S.A., Inc.	60,900
Reece Corporation	10,330
Rimoldi	7,000
Singer Sewing Company	18,000

STAG, Inc.	11,000
Stone Mountain Handbags	2,000
Sunbrand/Barmish, Zeidel and Associates	21,000
Ticket Pac	12,000
Union Special	26,226
YKK, Inc.	16,000
<b>TOTAL</b>	<b>\$1,749,000</b>

**2.2.3 Demonstration Site/Facility** - The Georgia Tech proposal which resulted in a contract award from DLA committed the use of the W. Clair Harris Center of Excellence for Apparel and Textile Technology on the campus of Southern Tech for the new Apparel Manufacturing Technology Center. This facility was in the planning stages at the time of the proposal (August, 1986), and was to be built with a \$1 million grant from the Governor's Research Consortium, an economic development initiative whereby funding for new, high-technology programs at selected units of the University System of Georgia receive capital improvement funds to support the programs. In addition to the state funding, the construction of the Harris Center was made possible by a bequest from the estate of W. Clair Harris (\$500,000), a distinguished Southern Tech graduate. Also, \$700,000 was secured from the industry, at large, for facility construction and equipment.

The Harris Center was planned as a 22,000 square foot facility which would house both laboratory and classroom space. The DLA award was made at a time when planning of the interior space of the Center could accommodate the proposed AMTC. Table 2.3 gives a description of the physical facilities of the AMTC, as it was proposed for installation in the Harris Center. Construction on the Harris Center began in September, 1987, and the building was dedicated on September 26, 1988.

The design and layout of the pilot plant in the new facility was designed by a team of senior

Georgia Tech Industrial Engineering students. Appendix E contains photographs of the facility and Appendix F contains this initial design.

**Table 2.3**  
**Physical Description of the AMTC**

Location	On Southern Tech campus in Marietta, GA
	Easy access to Atlanta/Hartsfield Air Terminal (30 minute drive)
	Within 15 miles of two cooperating apparel manufacturing facilities
Building	22,000 square feet total floor space
	New construction, dedicated September, 1988
	4800 ft <sup>2</sup> high bay/labs (5)
	2800 ft <sup>2</sup> classrooms (4)
	920 ft <sup>2</sup> X 80-seat auditorium
	8200 ft <sup>2</sup> administration offices, faculty/staff offices, conference room, restrooms, and mechanical
Services	220/440 volt electrical service w/floor trenches in lab space
	110 PSI air supply
	22 personal computers in training classroom
	IBM AS400 and HP 3000 minicomputers operating manufacturing software
	Satellite up and downlink for receiving video courses
	Telephone service
	Photocopying and FAX services

**2.2.4 Conducting Technology Demonstrations** - The concept of technology demonstration is one that has been employed for years by the federal government in order to facilitate the transfer of technology to new users who might not otherwise be aware of it. In general, government funds are allocated to technology demonstrations to facilitate the diffusion of a certain technology or group of technologies. In support of this diffusion, agencies funding demonstrations hope to produce new information on the demonstrated application of technologies, and disseminate information already known about the technology or technologies. An extensive study by the Rand Corporation in 1976 evaluated the results of a number of federal technology demonstrations and found that successful demonstrations were ones where:

- The technology being demonstrated was 'well in hand' (i.e., not experimental);
- Costs and risks involved were shared by non-Federal participants;
- The project initiative was at the local level;
- A strong industrial base for technology commercialization exists;
- Those who will take further responsibility for diffusion participated in the demonstration, as mentors; and
- There was an absence of tight time constraints.

The AMTC technology demonstration facility endeavors to embody all of these factors for success.

The initial demonstration of the AMTC microfactory operation was on October 21, 1988. Since that time 197 scheduled demonstrations and approximately 75 informal demonstrations have been conducted for a total of 16,646 visitors.

**2.2.5 Staffing and Administering the Demonstration Facility:** The core operations and maintenance staff for the facility consists of skilled individuals with substantial apparel



manufacturing experience. They have been hired by Southern Tech, and presently include:

Mr. Bill Cameron, who has over 33 years of experience as an apparel manufacturing consultant, is the Associate Director and Facility Manager of AMTC. He is responsible for the setup and operation of the facility, and he personally teaches courses for apparel managers at the facility.

Mr. Howard Pettigrew, AMTC Research Technician, is responsible for maintenance and operation of the equipment in the demonstration facility. He has 20 years experience in sales and service of sewing equipment and in supervising mechanics in a major apparel firm.

Ms. Carol Ring, AMTC Lab Technician, is responsible for hiring and training operators who run demonstrations at the facility. Ms. Ring has 20 years experience in apparel manufacturing at the operator level through plant manager level.

Mr. Dave Williams an industrial engineer who served as Director of Engineering for a major Georgia apparel firm for 20 years, consults regularly with AMTC on Computer Integrated Manufacturing projects. He is a specialist in apparel computers and software.

On-site management for the Southern Tech facility included Professor Larry Haddock, who serves as industry liaison and Academic Programs Director, and Dr. Bill Rezak, Dean of the School of Engineering Technology and chief administrator for the Southern Tech operations.

In addition, students in Southern Tech's Apparel and Textile Technology program are employed to assist in operating the microfactory for both training and demonstration purposes. Operators and other equipment resources are regularly donated by apparel firms to assist in microfactory operations.

Administrative support for the demonstrations are provided by Georgia Tech. The demonstrations are often held in conjunction with workshops, which are conducted by Georgia Tech and Southern Tech faculty, administrative support staff, and students.

### **2.3 Establishing an Apparel Industry Coalition**

One of the first efforts, once a contract was in place, was to establish an Industry Coalition. Also an Advisory Board, acting as a Board of Directors, was recruited. The Coalition would initially function as an active group of program participants who would be initial assimilators of AMTC technology and the primary beneficiaries of the AMTC demonstrations and research, and would provide in-kind support for these program elements. Lists of the initial Advisory Board members and the members of the Industrial Coalition are included in Appendix A.

### **2.4 Developing and Demonstrating Non-Traditional Capital Investment Criteria**

**2.4.1 Background:** The traditional methods of evaluating equipment investment, as used in the apparel industry, are dominated by the simple payback period. Nontraditional investment criteria emphasize qualitative, strategic factors as well as quantitative measures of viability. The qualitative methods are various configurations of scoring systems which enable the decision-makers to incorporate the perspectives of diverse interests within the firm, e.g., finance, production, and marketing. The quantitative nontraditional methods, while using the basic structure of the net present value, include items traditionally excluded, such as quality.

The goals of this endeavor were to, first, examine the practices of the apparel industry in their equipment investment decisions; second, to review the options available to the apparel companies to improve the quality of their equipment investment decisions, and, third, to develop a strategy and the tools for implementing the identified potential improvements. This project has been divided into two phases. The first phase was completed in 1988. The second phase was completed in 1993. The research team developed a self help tool called COMPASS to enable the plant operating staff to systematically evaluate investment opportunities.

**2.4.2 Assessment of Apparel Industry Practices:** It was a common perception among apparel industry observers that U.S. apparel companies were not investing sufficiently in the new, more productive equipment that is commercially available. A survey was developed and executed to

test this perception and to define how decisions were made, what equipment was being considered, what equipment was accepted and what was rejected, and why.

The survey population consisted of firms who had expressed an interest in the work at AMTC. Supporting research, such as AMTC, indicated significant interest of the firms in new ideas and approaches. The general success of these firms, in the face of enormous international competition, is indicated by the large percentage (42%) which had grown steadily over the previous 5-years, as opposed to only 12% which experienced falling sales.

These firms also confirmed, in general, the perception of narrowly focused equipment investment evaluations applied within a very short-term time horizon. Most firms indicated a strong attraction to the AMTC pilot plant to test equipment and techniques before introducing it to the factory floor. While discounted cash flow techniques were used in 48% of firms surveyed, 69% reported the payback period (or its inverse, the return on investment), as the dominant decision criteria. These profiles, surprisingly, were fairly consistent across firm size and market situation. Small firms were, however, shown to use less formal decision methods, which were closer to the spirit of the nontraditional methods, with greater frequency than either medium or large firms.

In other questions asked on the survey, it was shown that reducing labor cost continues as the most important factor motivating equipment purchase while meeting long-range strategic planning goals like reducing lot size or time to market was the second lowest in importance. New factory products were the lowest in importance. There were indications, however, that firms were moving toward an integration of their strategic planning and equipment purchases and they also indicated overwhelmingly that training in new methods of equipment evaluation would be of focus.

**2.4.3 Identifying Options for Improvement:** The literature review conducted as a part of the first phase of this project revealed broader concerns motivated at least in part by the investment opportunities available to, and rejected by U.S. firms but successfully exploited by the Japanese,

for example. The gist of the conclusions by the many authors on this subject was that, 1) the emphasis on short-term profitability excluded many worthwhile investments, 2) the characteristics of the new technologies produced benefits not normally quantified and incorporated into an analysis, and 3) the degree of specialization within the firm did not allow strategic factors to be successfully integrated into the decision-making process. All of these factors can be addressed in newer nontraditional investment analysis.

### **2.5 Operating an Apparel Manufacturing Technology Dissemination Service**

Using training and information dissemination for technology transfer is a technique that has been proven in well-established programs such as the Cooperative Extension Service for U.S. agriculture. The AMTC was conceived under the strong influence of industrial extension programs already in place at Georgia Tech. These programs, representing over 30 years of experience in transferring technology to small and medium-sized manufacturing firms, have demonstrated the efficacy of information services.

The AMTC has established an apparel manufacturing technology dissemination service which consists of the following elements:

- 1) An advisory board of industry representatives from the apparel manufacturing sector formed to act as a conduit for information dissemination and guidance for AMTC operations and initiatives.
- 2) Workshops on relevant technology topics selected by the AMTC industry coalition.
- 3) Newsletters which inform the reader of what's happening at the AMTC and of other technology developments.
- 4) Technical briefs which offer succinct overviews of new or emerging technologies for apparel manufacturing.
- 5) Focusing transfer of advanced technologies and techniques in plants of industry innovators. Then, facilitating these plants to encourage widespread adoption via testimony and mentoring.

- 6) An annual contract briefing, held at the demonstration facility, which provides apparel industry leaders with an in-depth presentation of the AMTC's previous year's activities and results.
- 7) Involvement and education of students from both Georgia Tech and Southern Tech in operation of the demonstration facility, conducting the workshops, preparing publications, and conducting the research. These students, who often are hired by the apparel industry, offer one of the best avenues of disseminating information and knowledge of the AMTC technologies.
- 8) Presentations of research findings from AMTC research projects.
- 9) Technical assistance projects by AMTC staff.

**2.5.1 AMTC Industry Coalition:** When the original proposal to establish the AMTC was made to the Defense Logistics Agency, a number of apparel firms were approached to solicit their support for the proposed center. When the award was made, these industry contacts served as the first contacts in establishing the Industry Coalition to provide guidance and initial assimilations of AMTC technology. The Coalition, which has involved over 250 apparel companies, represents an active network of apparel firms who value and support the Center and its projects. This network is an effective technology dissemination tool because it facilitates rapid dissemination of initiatives and project results. It also provides feedback on operations through both formal and informal responses to surveys by AMTC staff.

**2.5.2 AMTC Workshops:** One of the first actions of the industry coalition was to develop a priority list for workshop topics. The first workshop on Modular Manufacturing was conducted at a hotel near the demonstration facility in April, 1989. Since that time, 57 workshops have been conducted with a total attendance of 1088.

A typical workshop is advertised with a mass mailing to approximately 1800 individuals about two months in advance. The sessions are usually held in conjunction with special technology demonstrations at the Southern Tech facility to complement the classroom presentations. A registration fee range from no-cost to \$125 per person was collected to offset expenses.

**2.5.3 AMTC Newsletter:** The *AMTC Quarterly* was first published in August, 1988. The format is a two-color, four-page, 8 1/2" x 11" newsletter, with black and white photos. The cover story is devoted to news on the AMTC, usually focusing on the demonstration facility at Southern Tech. Articles on the second, third and fourth pages address technology topics of current interest to the industry and tie in AMTC research, where possible. When there is a workshop or meeting associated with the center scheduled, an announcement(s) is included.

Due to the budgeting constraints, the newsletter was discontinued after 9 issues.

**2.5.4 AMTC Technical Briefs:** A one-page brief on specific technology topics has been published on six occasions. These are titled *AMTC Tips* and are distributed through mailings and at the demonstration facility. In addition to technical information, they specify individual AMTC staff members to contact for additional information.

**2.5.5 AMTC Annual Contract Briefing (ACB):** The ACB is intended to summarize each year's activities and transfer the results of AMTC operation to a select group of apparel industry leaders. The first ACB was held on February 2-3, 1989. Meetings were conducted yearly thereafter with the event usually occurring in the third week of August.

**2.5.6 Research Presentations:** The research findings are regularly presented to professional organizations, both those associated with the apparel industry and others focusing on generic technology areas. Articles for magazines and journals directed at the apparel industry have also been written by AMTC researchers. Finally, meetings of researchers in all three DLA-sponsored Apparel Advanced Manufacturing Technology Demonstration centers provide further opportunities to exchange information and findings with other researchers. Appendix D lists articles published and presentations made.

**2.5.7 Technical Assistance to Apparel Firms:** Based on the successful industrial extension model developed over 30 years at Georgia Tech, both formal and informal programs have been set up within the AMTC to respond to industry requests for technical assistance. Typically, a problem involving technology in an apparel plant is identified by an industry manager and an expert from the AMTC is dispatched to help solve the problem. In some cases, representatives from the plant come to the demonstration facility to discuss the problem and sometimes use the equipment to help find a solution. Over 176 technical assistance projects have been conducted throughout the contract period.

**2.5.8 Participation in Apparel Industry Associations:** Most of the AMTC staff and researchers are either members of or active contributors to professional and trade organizations which focus on the apparel and/or textile industries. Some of the organizations to which AMTC staff have made presentations are:

- AAMA Apparel Research Committee
- AAMA Apparel Education Committee
- AAMA Apparel Quality Committee
- AAMA CIM/COM Committee
- AAMA Government Contractors Committee
- AAMA Management Systems Committee
- AAMA Technical Advisory Committee
- American Association of Textile Chemists and Colorists
- American Apparel Contractors Association
- American Society of Quality Control

- Association of College Professors in Textile and Clothing
- Atlanta Textile Club
- International Association of Clothing Designers
- Georgia Department of Technical and Adult Education
- Georgia Textile Education Foundation
- Georgia Textile Manufacturers Association
- Sundries and Findings Linkage Committee
- Society of Manufacturing Engineers, Atlanta Chapter
- Textile Apparel Linkage Council
- The Network ( of Minority Professionals in the Apparel Industry)

These linkages, together with interaction with the AMTC Industry Coalition, help the center's staff maintain a perspective on the technology issues and priorities of the industry. Also, feedback on the activities of the center are garnered from interactions with 'front-line' organizations such as these.

## **2.6 Conducting Applied Research**

Apparel manufacturing in the future will probably occur in one of three general manufacturing environments. Commodity products will be produced in highly automated plants with high ply cutting and some modification of the current bundle system in assembly. High fashion products will be produced in modular plants with single-ply cutting and with each garment progressing through assembly as a single unit. Third, some plants will adopt a hybrid manufacturing system with subassemblies manufactured in highly automated units and three dimensional assembly occurring in modular manufacturing units with production restricted to lots of less than 100.



Since military garments are produced in large volume, it is probable that they will continue to be manufactured in a manner similar to commodity apparel products. This type of production system has, therefore, received greatest attention in the Georgia Tech and Southern Tech AMTC research effort.

A typical large volume apparel production facility normally consists of 4 types of operations:

- Fabric receipt, spreading, cutting, bundling
- Subassembly manufacture (serging, 2-dimensional sewing)
- Final assembly (Subassemblies combined in 3-dimensional sewing)
- Finishing (pressing, inspection, packaging)

The subassembly manufacturing step which comprises about 50% of the typical apparel assembly operations has received the greatest attention in development of automated systems. Most of the current systems developed for subassembly manufacture are worker assisted units which are capable of producing only one specific part (shirt cuffs, shirt collars, trouser pockets, etc.). These workstations are highly inflexible and, in the few cases where more than one part can be produced on a machine, changeover times are long and require technicians to effect the change.

Automated apparel assembly in the future will be carried out on automated workstations that do not require workers and that are sufficiently flexible to permit a variety of subassemblies to be produced on each machine. These workstations will accept as inputs stacks of cut parts and will produce as outputs finished subassemblies. The workstations will be built around a fast and accurate programmable robot with the ability to quickly dock the appropriate sewing or joining device needed for the assembly being manufactured. The units will be capable of changeover from one subassembly to another in a few minutes with direct downloading of assembly instructions to the robot from a central computer.

A survey of the Advisory Committee in May, 1988, was conducted to gain an industry perspective and to assist in establishing research priorities for the AMTC. The results of this

survey are presented in Table 2.4, and many of these support the concept of an Automated Flexible Workstation.

**Table 2.4**  
**Research Priorities Established in 1988 Industry Survey**

#1	Develop in-process quality control in apparel production.
#2	Utilize automated flexible work cells for apparel manufacturing.
#3	Investigate the applicability of flexible work group methods for manufacturing military trousers.
#4	Develop shop floor control systems for an apparel assembly plant.
#5	Investigate cut order planning algorithms.
#6	Develop sales history analysis and production forecasting and planning models.
#7	Investigate manufacturing techniques in the apparel industry.
#8	Apply discrete event simulation to apparel manufacturing.
#9	Develop fast, low-cost vision systems for flexible automated apparel assembly.
#10	Develop planning techniques for labor requirements in apparel manufacturing.
#11	Develop an efficient trouser plant design.
#12	Develop a self-study course for apparel supervisors in the practical application of ergonomic principles in apparel firms.
#13	Design military utility trousers for automated assembly and manufacturing compatibility.
#14	Investigate textile-apparel interfacing.
#15	Investigate computer-aided design software.
#16	Investigate utilization of Kawabata Evaluation System data in apparel manufacturing.
#17	Develop equipment modifications for improved utility trouser assembly (automatic fly making).
#18	Develop equipment modifications for improved utility trouser assembly (pocket setting).

#19	Design and develop a data base of standard unit operations and costs.
#20	Develop facilities planning methods for an apparel manufacturers.
#21	Implement an energy audit program for apparel manufacturers.
#22	Demonstrate applicable energy conservation measures for the apparel industry.
#23	Investigate standardization of uniform sizes.
#24	Provide organization development services to selected apparel manufacturing firms.

Development of the Automated Flexible Workstation will require several technological advances. A number of these advances are part of the research effort at the AMTC. Communication systems that permit the workstation controller to send and receive information from the central plant computer will be essential for flexible operation. This communication is part of computer integrated manufacturing (CIM) which is the topic of one of the AMTC research projects. related work is underway at other apparel research centers in the U.S.

A flexible assembly workstation will require new systems for location of parts, registration of parts being joined, and positioning the parts relative to the needle. New, low cost vision systems for apparel manufacturing is the subject of another AMTC research project. Vision technologies developed at Georgia Tech as part of research on automatic guided vehicles appears to have promise for application in apparel assembly workstations. These and other low cost vision systems will be the subject of further research at the AMTC.

An important aspect of automated workstations that must be addressed is the assurance of quality in automated systems. This function is provided by operators in current apparel assembly. Two projects are currently funded that address this important area. First, a system is being developed to automatically detect fabric defects in cut parts, to measure the color of each part and to stack parts in a configuration suitable for input to the first automated workstation. This system will insure that the automated assembly operations are supplied with a set of defect-free, properly cut, and color matched parts.

The second quality assurance project is directed toward insuring that the sewing machine in an automated workstation is performing properly. This project will develop detection systems to determine if a sewing machine is making stitches correctly and if the machine is sewing the correct number of plies of fabric. Such systems are essential to prevent the manufacture of large numbers of defective parts in an automated workstation.

Although not a part of the AMTC research program, work is being conducted as part of the Computer Integrated Manufacturing Systems Program at Georgia Tech to evaluate the feasibility of using a commercially available fast robot to manipulate flexible materials and to automatically orient and guide these flexible parts in a complex sewing operation. Integration of the robot operation with a vision system is part of this effort under this research program.

Thus, a number of important technologies that will be required for development of an Automated Flexible Workstation are underway as part of the research effort of the AMTC. These projects will not only advance the state-of-the-art in existing apparel assembly operations, but will provide also the technology base for the next generation of automated apparel assembly equipment.

Managing issues related to establishing a supplier chain architecture to reduce time to market has been worked extensively at Georgia Tech. The fundamental building block for organizing the supply system is addressed in the Apparel Manufacturing Architecture (AMA) endeavor which creates the basis of a seamless flow of critical information both vertically and horizontally in the supply chain. The tool is fully developed and being production hardened at a DOD supplier facility.

### **2.7 Student Involvement in AMTC**

Because well educated students are a primary output for a university, Georgia Tech and Southern Tech strives for maximum student exposure to AMTC technology. Well trained students equipped with the understanding of the value of advanced technology and of the techniques to implement it are a primary venue of technology transfer at AMTC.

The AMTC demonstration facility and other technology dissemination activities offer excellent

opportunities for students at Georgia Tech and Southern Tech to be exposed to and learn about the manufacturing technology being transferred. Students can have a unique learning experience in the laboratory setting that the demonstration facility represents and, at the same time, be in contact with representatives from the apparel industry who might influence the students career choice. Also, students are used in research projects which gives them insight in the problems and possible future technologies facing the industry.

The AMTC has offered excellent opportunities for Georgia Tech and Southern Tech faculty to attract and employ undergraduate students. Of the two schools involved, Georgia Tech's Fiber and Textile Engineering School has had undergraduate enrollment more than double since the AMTC was established, and undergraduate enrollment in Southern Tech's Textile and Apparel Technology Department has increased 53% during the same period. Although other factors certainly contribute to these increases, the existence of the AMTC is definitely an asset to support student recruitment.

### **3. RESULTS AND BENEFITS ACHIEVED**

Since the DLA award was made in August, 1987, the AMTC has been actively promoting the use of modern manufacturing technology and management systems to the U.S. apparel industry. The following is a list of significant accomplishments and milestones that have been achieved:

#### **3.1 Operation of AMTC Demonstration Facility**

After the DLA award for the AMTC was made, Georgia Tech subcontracted to the Southern College of Technology for participation in establishing and operating the center. Southern Tech made a commitment of space for the demonstration facility in the W. Clair Harris Apparel and Textile Center of Excellence. Construction of the Harris Center began in late 1987 and the facility was ready for occupation in September, 1988.

**3.1.1 Facility Development:** The Harris Center is located on the Southern Tech campus in Marietta, Georgia, just north of Atlanta. This site is ideal for access by the apparel industry in Georgia and the southeast because it is readily accessible from Atlanta's Hartsfield International Airport and major interstate highways. The location of AMTC on a college campus facilitates its use by students and educators, as well as providing excellent classroom and meeting accommodations.

Because the building housing AMTC had not been constructed at the time of the DLA award, provisions were made to assure an effective facility was created for demonstrating new technology. In addition, the strong ties which Southern Tech's Apparel and Textile Technology program has with the industry resulted in widespread industry knowledge and support of the AMTC, even before it was completed. The AMTC is very much an integral part of the Harris Center and can be considered to be the focal point of this Southern Tech facility/activity. Because of this, one of the best outcomes of creating the AMTC as it was is the role it plays as part of both Southern Tech's and Georgia Tech's educational programs for the apparel and textile industries.

The AMTC technology demonstration consisted of a pilot plant for manufacturing Navy workpants, BDUs, and other types of trousers, and a Computer Aided Design/Pattern-making lab. The equipment layouts for these two rooms were developed through a senior engineering design project by students in Georgia Tech's School of Industrial and Systems Engineering. The results of the design project are contained in Appendix F. The location and physical plant of the AMTC, together with its affiliation with both Georgia Tech and Southern Tech, have proven to be strong assets for its operation. An estimated 16,646 visitors have toured the center since it was formally dedicated in 1988.

**3.1.2 Equipment Procurement:** Immediately after DLA awarded the contract for the AMTC, Georgia Tech and Southern Tech faculty began contacting equipment vendors to solicit donations/consignments to the center. While Georgia Tech has successfully equipped R&D

facilities in the past by attracting equipment donations, the AMTC represented the first effort to secure equipment which could constitute an entire microfactory for a specific industry.

Table 2.2 lists the initial equipment vendors who donated or consigned equipment or software for use in the center. In some cases (e.g., unit production systems), the AMTC management had different options to choose from in selecting equipment that was offered. The equipment that was eventually placed in the facility was selected using the following criteria:

- Need as determined by manufacturing capabilities desired,
- Initial cost based on consignment, lease, or discounted purchase,
- Installation, maintenance and service offered,
- Assurance of upgrades and improvements, as they became available,
- Interest of vendor in joint R&D with the center.

The first equipment items were installed in the facility in September, 1988, and by January, 1989, the demonstration facility was equipped sufficiently to demonstrate the manufacture of the Navy denim workpants, the production item assigned by DLA to demonstrate at the AMTC. In the first demonstrations, operators for the equipment were supplied by nearby apparel plants, including the H.D. Lee Company and the Arrow Shirt Company. In later demonstrations, Southern Tech students who had trained in the center were used as operators.

**3.1.4 Cost-sharing:** The contract with DLA required cost-sharing from Georgia Tech in the amount of \$666,666 for the initial three-year period covered by this report. The actual value of cost-sharing provided by Georgia Tech, Southern Tech, equipment vendors, and participating apparel firms is \$4.23 million. Appendix G gives an accounting of some equipment donated to the AMTC for its operations. In addition to the donations from technology vendors, the participating schools have made the following cost-sharing contributions of both university system

funds and in-kind services:

Georgia Tech (\$228,000 cost-sharing contribution): Much of the development of computer models for AMTC have utilized the computing facilities at Georgia Tech, and the laboratory facilities of the School of Textile and Fiber Engineering have been used to support AMTC research projects. Computer hardware, software and support valued at \$190,000, and in-kind management and support personnel valued at \$38,000 have been provided by Georgia Tech. In addition, the Industrial Extension Service and Southeastern Trade Adjustment Assistance Center at GTRI have both contributed to the promotion and services of the AMTC. These programs provide technical assistance to apparel manufacturers in Georgia and the Southeast and have collaborated extensively with the newer AMTC.

Southern Tech (\$97,700 cost-sharing contribution): The AMTC technology demonstration facility has been in its current physical configuration on the Southern Tech campus since September, 1988. This layout and the specific equipment included was designed to demonstrate the manufacture of the Navy workpants, a military garment selected jointly by Georgia Tech, Southern Tech and DLA, after the AMTC contract was awarded. The facility design incorporates the latest technology in:

- Computer aided design (CAD),
- Pattern-making,
- Fabric spreading and cutting,
- Unit Production Systems for material handling,
- Specialized sewing equipment and attachments
- Computer-based production tracking,



- Ergonomic workstation.

Southern Tech has contributed space for the microfactory, office space, classroom/meeting space, utilities, in-kind management, secretarial and student employee support, telephones, office supplies, and bar-code reading hardware, all of which is valued at \$97,700 for the initial 3-year reporting period.

In addition, the State of Georgia has contributed \$1.5 million in equipment funding, and the Woodruff Foundation has contributed \$700,000 for the establishment of the Teaching Factory discussed below.

**3.1.5 Staffing:** The center has a host of staff resources to draw upon for operating the demonstration facility. The principal responsibility for keeping the facility operational lies with Southern Tech. For the first 1 1/2 years of the facility operation, Dr. Larry Haddock, head of the Apparel and Textile Technology Department was the Operations Manager. However, recognizing the need for a full-time, dedicated facility manager, Mr. Bill Cameron was hired as Associate Director of the AMTC in May, 1990. Bill has management responsibility for the physical plant of the AMTC and he reports to Mr. John Adams, the AMTC Director. As indicated in Section 2.2.5, Mr. Cameron is assisted by Ms. Ring and Mr. Pettigrew, as well as by Southern Tech students, Georgia Tech faculty and staff, and industry representatives. The demonstration facility has accomplished the goal of causing college/university staff, equipment vendors and apparel manufacturers to work together in promoting and developing advanced manufacturing technology.

**3.1.6 Research Support:** The demonstration facility has been used as a laboratory in support of the following research projects:

- 1) "In-Process Quality Control: Fabric Defects"
- 2) "In-Process Quality Control: Sewing Defects"
- 3) "Improved Marker Making Systems"
- 4) "Cut Order Planning"
- 5) "Flexible Work Group Methods Applied to Apparel Manufacturing"
- 6) "Apparel Manufacturing Architecture"
- 7) "Ergonomic Supervisor Training"

**3.1.7 Workshops and Demonstrations:** The pilot plant demonstration facility has been used in conjunction with every AMTC workshop and demonstration conducted. In general, the one-day workshops begin with a classroom session for 4-6 hours, and the participants are then taken to the demonstration facility to witness tangible examples of the principles covered by lectures or panel discussions. For example, the workshop on ergonomic principles included a demonstration of an ergonomically designed workstation and proper operator posture in the demonstration facility. The workshop topics were selected by surveying the Industry Advisory Committee and by assessing the availability of high quality speakers from industry and other sources. Typically, speaker panels made up of experts from the apparel industry, universities and government were used to address topics through both formal presentations and question and answer sessions.

Demonstrations are defined as formal sessions scheduled to showcase the entire range of technology installed in the facility, or highlighting specific items or areas of advanced apparel technology. In general, the AMTC staff attempts to offer a credible simulation of an apparel plant environment, allowing those attending plenty of time to ask questions and get a 'hands-on' feel to the technology. In some cases, special pieces of equipment are brought in for demonstration and vendors who donate or loan such equipment have the opportunity to showcase their products.

This method of technology transfer is common within the apparel industry, as evidenced by the industry's annual Bobbin Show held each fall in Atlanta.

The AMTC facility is readily available to any interested party, and is used by Georgia Tech and Southern Tech staff for both technology demonstrations to potential users and education of students and workshop attendees. In some cases, the center has accommodated specific requests from apparel firms or equipment manufacturers to privately demonstrate pieces of equipment. Annually, Southern Tech's *Techfest* campus open house promoting advanced technology and technical education draws over 2,500 visitors through the center. These visitors were from the general public and the occasion provided excellent promotion for attractive employment in the apparel industry.

Accurate records of visitor profiles to the center were started in January, 1990, and Table 3.1 gives a breakdown of these since that time.

**Table 3.1**  
**Characterization of Visitors to AMTC in 1990**

Visitor Category	% of Total
Apparel Manufacturers	30%
Textile Manufacturers	4%
Equipment Manufacturers	8%
Other Manufacturers	1%
Educational Representatives	45%
Government Representatives	8%
Media Representatives	1%

**3.1.6 Additions and Improvements:** The demonstration facility is constantly evolving with respect to types of technologies and processes included. Most of the agreements under which vendors placed equipment in the AMTC included a provision for upgrading the technologies in a timely manner. As a result, a number of equipment items and systems have been changed out for upgrades during the five years the facility has been open for demonstrations.

**3.1.7 Student Involvement and Education:** Students have been an integral part of the staff for the demonstration facility since it was dedicated in 1988. The faculty and administration for Southern Tech's Apparel and Textile Technology Department is housed in the Harris Center, and classes for the apparel technology students are regularly held in the center. The demonstration facility is used for laboratories in support of the department's degree programs (Bachelor and Associate), and students are employed to help operate the facility. Georgia Tech undergraduate co-operative students and graduate research assistants are involved in the facility as assistants to faculty conducting research and to assist in conducting the workshops.

Students working in the AMTC are constantly exposed to leaders from the apparel industry, thereby providing them with opportunities to learn more about the industry and with a chance for a unique 'networking' with potential employers.

### **3.2 Demonstration of Non-Traditional Capital Investment Criteria**

The conclusion of Phase 1 of the nontraditional economics project contained a strategy to improve the quality of the decisions made in the apparel industry regarding equipment purchases. This strategy recognized several factors, and limitations of our role as change-agents for the industry. First, a completely successful program would change many things about the corporate culture of the apparel industry. Realistically we were not expecting to be this successful. Rather, we hoped to influence the way equipment decisions were made in a few of the firms considered industry leaders, and subsequently, expanding our contact with more firms. This is being accomplished via training programs. The first year, the training will be offered free to a selected

group of firms; in subsequent years, additional offerings of the course, with firms paying the cost of the training, designed to reach a wider audience.

The content of the training also takes into consideration what we have learned about the apparel industry. It is considered unlikely that many apparel firms would be receptive to an abandonment of the quantitative measures so prevalent. Rather, it is our intention to shift the focus of the quantitative analysis toward the discounted cash flow techniques while also providing guidance and prompting for including a broader range of factors in the analysis. This will encourage a consideration of factors not now included in a quantitative analysis (such as quality, or de-skilling an operation), and an analysis of how the firm might be affected by long-term trends, such as labor availability, time to market, or demands for new services by its customers.

The nontraditional, qualitative, evaluation procedures are also being presented in the training. The real value of this methodology is expected to be in the lines of communication established between the production, finance, and marketing groups within the firm as they are required to focus upon presenting their distinctive perspectives evaluation of equipment.

The second phase, completed in 1993, produced software and documentation of value to firms, vendors, and researchers. While the software tool (COMPASS) can be used as a stand-alone product, the greater value will be realized combining the software with training.

### **3.3 Operation of an Apparel Manufacturing Technology Dissemination Service**

The many facets of technology dissemination effected through the center have succeeded in getting apparel firms interested in the facility, and have garnered significant support for workshops, research projects and technology demonstrations. The most tangible support for the center has been from equipment manufacturers who view their contributions of equipment and service as a useful promotion of their products to potential customers. Apparel manufacturers have also participated in the center's activities with in-kind support of individual research projects and with attendance at the workshops and demonstrations.

This support is evidence in that there is a need for a forum in which apparel manufacturers can learn of new technology. It is clear that the most active industry participants in AMTC activities

are the larger, more progressive firms who view the center as an extension of their own innovativeness. For these reasons, DLA has chosen to focus the center's activities in the future on 1) contractors manufacturing garments for the Department of Defense (DOD), 2) time to market issues which offer the greatest defense against low wage foreign producers, and 3) technologies which have near-term commercialization potential. With this focus, DLA hopes to reap more direct benefits for DOD as a result of its investment in the centers.

When evaluating the results of the center's operations and the attendant benefits, the concept of using a university-based center for stimulating the transfer of advanced technology to U.S. apparel firms has been proven effective because:

- 1) Schools such as Georgia Tech and Southern Tech have well-established reputations in the area of technology 'know-how.' Many managers who visit the center comment that they are graduates of one of the schools. In addition, Georgia Tech has over thirty years of experience in transferring technology to industry.
- 2) The center has created a showcase for off-the-shelf technology which is not strictly a vendor-specific demonstration. Although the manufacturers of the equipment in the demonstration facility are recognized, there is no effort by the AMTC technical staff to promote one vendor over another. This lends an air of objectivity to the presentation of technology. This environment enables industry the opportunity to "drive before you buy".
- 3) Universities are excellent facilitators of continuing education classroom learning. Further, Georgia Tech and Southern Tech have active workforce education programs and are experienced in conducting short courses and workshops for industry.
- 4) One of the greatest advantages of the center is the involvement of students who learn about both the apparel industry and the new technology that can improve competitiveness. This learning experience represents an excellent recruiting opportunity for apparel firms to hire the students.
- 5) A university is unique in its ability to collectively offer education, research, and facilities with a specific technology focus, while simultaneously involving students.

The following sections address the results of AMTC operations and discuss the resultant benefits to the apparel sector.

**3.3.1 Workshops and Seminars:** The workshops were well-attended with an average attendance of 21 and peak attendance of 63. In efforts to maximize interaction with attendees, many workshops were deliberately restricted to small groups. The selection of workshop topics and speakers seem to be responsible for the success in attracting enthusiastic industry participation. An examination of the registration files indicates that few individuals came to more than one workshop, although some firms regularly sent registrants. The impact of the workshops and attendant demonstrations can be gauged by the number of registrants willing to invest in their participation and the feedback (i.e., workshop evaluations) collected after they participated. The typical workshop registrant came from within 200-300 miles of the center (i.e., from Georgia or a bordering state), spent one night in Atlanta, and paid a registration fee of \$60. Evaluation surveys were collected from a over a third of the total registrants indicated an over whelming 92% satisfaction that the workshop objectives were met..

The workshops have been well received based on the registration response and the subsequent evaluations. We have drawn the conclusion that "keeping an ear to the ground" helps us select good topics for workshops. Georgia Tech's many years of planning and conducting workshops, short courses and conferences have contributed to the presentations and mechanics of the sessions being successful. Finally, the value of being able to utilize the technology demonstration capability of the facility on the Southern Tech campus is a strong element of the workshop successes. Together with the speakers from industry relating their own experience with technology, the demonstrations enhance the hands-on nature of the workshops.

While evaluation of the classroom portion of the workshops were solicited and compiled, formal feedback was not collected for the complementary sessions held at the demonstration facility. This feedback will continue to be collected for future workshops to determine the effectiveness of focused technology demonstrations in the center.

Discounting the possibility that those attending the workshops were dissatisfied, based on the positive ratings on the returned evaluations, it would seem that the workshops were effective in diffusing the information delivered throughout the apparel manufacturing sector in the Southeast.

**3.3.2 Technical Assistance by AMTC Staff:** Apparel firms have frequently interacted with AMTC as a source of knowledge and information on new technology. The most direct source of interaction has been the demonstrations of equipment items and systems at the facility. The Gerber Creative Design and Marker Making System have been very popular with apparel manufacturers because the center not only showcases the state-of-the-art CAD systems, but also has experienced operators on staff to effectively utilize the systems. In several instances, AMTC staff worked with firms to create new markers and patterns, resulting in savings of over \$45,000 per year in fabric costs.

The vendors who have placed equipment in the center have also used the facility for demonstrations to potential customers. AMTC staff have worked with equipment manufacturers to evaluate design and performance of specific hardware and software.

In many instances, AMTC researchers and staff have been contacted for unsolicited consultations with industry to help a firm solve a technology-related problem. These contacts have been initiated through 1) direct contact with the Georgia Tech or Southern Tech expert during a visit to the center; 2) referrals from other industry contacts who know the experts and equipment available through the center; 3) through the Georgia Tech Industrial Extension Service, which often refers Georgia industries seeking advice or assistance to campus-based experts; and 4) through contacts made as a result of presentations made by AMTC staff.

Once the referral is made, the AMTC staff member contacted will collect information relevant to the problem, often using the information retrieval services available at Georgia Tech. In some cases, a visit by the firm seeking assistance to the AMTC is arranged or the technical expert travels to the plant site for a consultation.

All AMTC technical staff are ready to respond to inquiries from industry. As the results of the short-term research projects are finalized, they are publicized (e.g., in the newsletter and through presentations) and promoted, thereby creating more inquiries for expert assistance from industry. It is expected that the existing system of informal 'networking' between apparel firms and AMTC staff will continue to grow and effectively serve the needs for technical assistance.



**3.3.3 Problem-Solving Projects:** Based on Georgia Tech's experience in several long-running technology transfer programs and an interest from both DLA and AMTC in establishing a formal program for comprehensive business analysis of apparel firms, a short-term task was funded early in 1990 entitled "Problem-solving for Apparel Firms." Since the inception of the program, AMTC staff members worked with 29 individual firms to solve specific problems in their operations. These problem-solving projects are cost-shared by the participating apparel firm and the AMTC, with the firm paying for 25% of the first phase (business diagnostic) and 50% of the second phase (implementation). DLA funds pay for the balance of the project.

Each project is initiated with a diagnostic phase consisting of one or two AMTC staff and an outside industry consultant spending 10-15 man-days to conduct on-site investigation and analysis of the firm. During this phase, the firm's strengths and weaknesses, areas for improvement, and recommendations for improvement strategies are identified. After this phase is completed, AMTC recommends improvement strategies which may or may not require further AMTC staff involvement to implement. Typical recommendations include:

- Installation of advanced manufacturing technology
- Modification of workstation design
- Modification of patterns and markers
- Retraining operators on improved methods
- Modification of plant layout for improved work flow
- Training and development for supervisors
- Modification of incentive systems
- Assistance with producing garments for the federal government

To date, seven firms have decided to pursue implementation projects with AMTC assistance.

**3.3.4 Newsletters and Other Publications:** The following publications have been produced by the AMTC:

- 1) A total of 9 issues of the *AMTC Quarterly* newsletter have been published. These have been mailed to 1800 apparel industry representatives and also used as descriptive literature for promoting AMTC to other individuals.
- 2) A total of 6 *AMTC Tips* have been published. These one-page technical briefs are widely distributed to apparel firm managers and offer facts and information on selecting and implementing new types of technology.
- 3) Workshop notebooks are given to each registrant at the workshops. These looseleaf binders included a compilation of articles and papers on the technology topic addressed during the workshop. They are intended to be used as easy reference manuals in an apparel plant environment.
- 4) Two videotapes have been produced for use in promoting the AMTC and its activities. The tapes are available for sending to apparel industry members who request information about the center.
- 5) A large number of letter mailings have been mailed to notify the industry of unique technology opportunities.

**3.3.5 Presentations at Trade Shows and Society Meetings:** The apparel industry is served by several major trade shows that are international in scope. These provide excellent opportunities to promote the activities and services of the AMTC. Appendix D summarizes various publications and presentations resultant of AMTC endeavors.

### **3.4 Research Programs**

The short-term research projects which have been funded during the seven-year reporting period are listed in Table 3.2. The projects have been aimed at addressing the needs for automation as discussed in Section 2.6 and developing solutions to high-priority technical problems. All research projects were funded based on proposals submitted to DLA, either as unsolicited proposals or in response to DLA-issued RFP's. All of the research projects have

involved industry collaboration, with "industry champions" designated for individual projects (see Table 3.2). Table 3.3 is a list of apparel firms who have actively participated in at least one research project by allowing AMTC researchers to collect data at their plant sites; providing software, equipment, fabric or other materials for testing purposes; installing equipment in their facilities for evaluation purposes; providing expert counsel on particular facets of research; or by participating in the problem-solving projects. Other companies collaborated with AMTC by taking part in surveys; however these are too numerous to list.

A description of the funded research projects is included in Appendix C. Each of these projects was conceived and conducted with eventual application for use by the U.S. apparel industry. In order to widely disseminate the results of the ongoing AMTC research, opportunities to make presentations or publish research findings are constantly sought. Detail final reports for each of the research projects are submitted under a separate cover.

Table 3.2  
Research Projects Initiated

	Project Title	Primary Industry Participant
1.	"Design and Development of a Generic Architecture for Apparel Manufacturing"	Oxford, Levi, Model Garment, Terry Manufacturing
2.	"Design and Development of a Knowledge-Based Framework for Trouser Procurement"	Defense Personnel Support Center
3.	"Analysis of Defects in Trouser Manufacturing"	Levi Strauss
4.	"Discrete Event Simulation Applied to Apparel"	Coastal Industries, H.D. Lee
5.	"Design of a Course for Apparel Supervisors in the Practical Application of Ergonomic Principles"	Tennessee Apparel, Statham Garment
6.	"In-Process Quality Control: Fabric Defects"	Coastal Industries, H.D. Lee
7.	"In-Process Quality Control: Sewing Defects"	Juki, Coastal Industries
8.	"Color Shade Analysis Demonstration for the Army Chief of Staff"	Defense Logistics Agency
9.	"Improved Marker Making Systems"	Superior Pants, Microdynamics, Gerber, Rivoli Mills

10.	"Cut Order Planning"	Russell Corp., Fashion Starr, Gerber Garment Tech
11.	"Flexible Work Group Methods Applied to Apparel Manufacturing"	Oxford Slacks, Russell Corp.
12.	"Measure the Effectiveness of AAMTD"	Defense Logistics Agency
13.	"Problem-Solving for Apparel Manufacturers"	29 Plants

Table 3.3

Firms Participating in AMTC Research

Altama Delta Corp.	Jet Sew
American Apparel	Juki American R&D
AMS Marketing, Inc.	KYM Company
Atlantis Program, Inc.	Lamsteel Company
Arc, Inc.	Levi Strauss and Company
American Apparel Manufacturing Assn.	M&W Sportswear
CDI Technologies, Inc.	Maid Bess Corporation
Camel Manufacturing Company	Microdynamics
Carla Gay Dress Company	Model Garment Company
Coats and Clark, Inc.	Nicolet Instruments

Coastal Industries	Okefenokee Impressions
Computer Dimension, Inc.	Oshkosh B'Gosh
Cone Mills	Oxford Industries
Connection Group, Inc.	Polygon Software Company
Dewitt Apparel, Inc.	Riverrun Enterprises
Dowling Textile Manufacturing Co.	Riverside Manufacturing Co.
DCASMA, Birmingham, Warner Robins	Rivoli Mills
DPSC, Philadelphia	Russell Corporation
Farah USA	Statham Garment Company
Fashion Star, Inc.	Superior Pants
Georgia Industries for the Blind	Swift Textiles
Gerber Garment Technology	Syntax Software Corporation
Graniteville Mills	Teledyne Brown Engineering
Greenwood Mills	Tennessee Apparel Corporation
H&H Manufacturing Company	U.S. Textile
Haggar Slacks	VF Corporation
Haggar Women's Wear	William Carter Company
H.D. Lee	Winfield Manufacturing Company

### 3.5 AMTC'S "Teaching Factory" Initiative

*The Initiative Summary:* AMTC's Teaching Factory is established as a partnership effort with Goodwill Industries of Atlanta. Goodwill Industries of Atlanta will operate a full time utility trouser apparel factory in conjunction with AMTC's pilot facility at Southern Tech.

*Why This Endeavor?* The teaching factory environment is a successful tool to launch important technologies and management methods into industry. The teaching factory provides a mentor for apparel manufacturers. Similar facilities exist in South Carolina (shirts) and North Carolina (dress trousers).

The pilot facility at Southern Tech alone cannot develop, teach and demonstrate some critical and important technologies and concepts due to limited scale operation (8 operators operating one day per week). Also, it is impossible to operate a balanced teaching factory in a university setting due to difficulty recruiting personnel (e.g. no established appropriate job classifications) and conducting manufacturing plant operations in the business and accounting environment of a university.

*The AMTC Teaching Factory Endeavor:* Establish a non-profit teaching plant at Goodwill Industries of Atlanta to act as a full time, operating factory and adjunct laboratory/teaching center for the apparel manufacturing industry. Industry will be provided virtually unlimited access to the Teaching Factory.

*How the Teaching factory will be established:*

- Equipment will be provided by AMTC (via state cost share dollars - approx \$420k).
- Facility modifications/start-up capital provided by a grant from the Woodruff Foundation (\$700k).
- Facility engineering provided by Georgia Tech/Southern Tech AMTC.

- Research, technology and teaching operations provided by AMTC via support from DOD apparel technology programs.

Factory operations are to produce 150,000 DOD apparel items (Battle Dress Uniform trousers) per year at a sale value of ~\$2.9 million/yr. The government provides a production contract that is a non-competitive set aside and non-profit arrangement. Also, some garments (seconds and training units) produced will be sold on the open market to facilitate cash flow during start-up. The facility will be operated with approximately 75 people with 75 percent of the wage earners being composed of disabled people (within 18 months of startup).

*Teaching Factory Mission:*

- Develop and disseminate techniques to assimilate inner city poor into the manufacturing environment.
- Develop and disseminate techniques to assimilate physically and mentally challenged into the manufacturing environment and enable them to develop the self esteem of being income earners instead of government benefits recipients.
- Develop and disseminate innovative manufacturing team concepts to improve apparel operators' job satisfaction via job enrichment techniques and improved compensation systems.
- Demonstrate manufacturing innovations in a production hardened environment including voice activated machine control, advanced materials handling/distribution, automated pocket setting, electronic commerce, above shop floor control, ergonomic operator practices, statistical process control, etc. via DLA's Apparel Research Network (ARN).

*Program Status:*

- Some equipment (~\$260K) has been purchased to be installed in the Goodwill facility.
- The grant of \$700k has been secured from Woodruff foundation and these funds are being spent to prepare the facility for apparel manufacturing.



- The concept is before DLA for consideration. Preliminary evaluation is positive.
- The set aside procurement contract for 150,000 BDU trousers per year is approved with the initial orders expected in March '95 (first shipments expected in July '95).

#### **4. LESSONS LEARNED in the AMTC PROGRAM**

***Lesson #1:*** The federal government is an effective catalyst for bringing universities and industry together in programs such as the AMTC. There are universities which have existing ties to specific industry groups, such as apparel manufacturers, but lack the resources or "foundation funding" to create well equipped and diversified centers. Where the government has either a customer-oriented interest (e.g., the DLA procurement system needs), or a policy interest, investment in select university/industry centers is effective.

***Lesson #2:*** The aggressive innovators in industry will be the first to recognize the value of a program like AMTC and will be the strongest participants and supporters. The less innovative firms which have the greatest need of technology transfer may not see as much value in participating or will be reluctant to participate. However, any impact on the more innovative firms is transferred to others because of the credibility, influence and perceived position of leadership these innovators possess.

***Lesson #3:*** Equipment vendors readily participate with in-kind donations and share the cost of a program like AMTC if it will showcase their technology. However, there may be little tangible short-term payoff for their investments (i.e., increased sales). Their payoff is longer-range R&D support from center activities to improve their products and stimulate customers to seek new technology oriented opportunities.

**Lesson #4:** Workshops and one-on-one contacts are the most effective way to promote interchange of ideas and transfer knowledge. This is because these meeting forums have no commercial ties. For this reason, industry executives freely interact and exchange information with both university staff and other executives. Publications are a more passive, but also important, secondary way to transfer technology which complements the face-to-face interactions. That is, publications can help maintain lines of communication, but should not be used as a primary means of technology transfer.

**Lesson #5:** Establishing finite time frames for accomplishing technology transfer may be unrealistic when working with a large, broadly defined and diversified industry group (i.e., U.S. apparel manufacturers). Credibility and working relationships take time to develop and nurture. Thus, adoption of innovations occurs at a faster pace as program life progresses due to growing credibility, expertise and influence.

**Lesson #6:** U.S. apparel manufacturers are actively seeking new technology which offers improved productivity and flexibility in manufacturing garments. Desirable new technologies should not be excessively complex (i.e., requiring significant new skills to operate and service) or expensive to purchase. These expectations may be both different from the expectations of their foreign competitors and difficult to achieve, from an equipment design perspective.

**Lesson #7:** Research projects are certainly most effective where they address a technology development need in the industry that is not otherwise being addressed. For example, the participating university may have expertise in software development which does not otherwise exist in the apparel industry. Research findings are valuable for informing industry managers of possible technological solutions to existing problems, and workshops and/or publications are very useful in disseminating these findings.

**Lesson #8:** Sustaining a university/industry technology transfer center solely from industry funding will be a difficult, if not impossible task, when the target industry is highly fragmented, is suffering general economic distress, and has not traditionally invested significantly in R&D.

**Lesson #9:** The seven-year operation of the AMTC has indicated that the ranking of different types of technology transfer activities, in order of relative effectiveness, is:

- 1) In-plant consultations with apparel executives and managers by reputable AMTC staff knowledgeable in apparel technology and management is most effective. These interactions offer immediate assistance in solving problems at the individual firm/plant level. This form of technology transfer is also costly.
- 2) Workshops and face-to-face meetings involving industry executives and AMTC staff are very effective. These, together with AMTC publications, offer excellent opportunities to transfer new or updated information to a number of apparel firms during a scheduled time.
- 3) Research projects addressing technology development needs of the industry are effective from a longer range perspective. These offer longer-term technology solutions which must be commercialized before widespread adoption by the industry can take place. Research significantly adds to the credibility and influence the AMTC has on industry.

Specific research and service needs recommended are:

1. More effort in labor recruitment and retention techniques.
2. More Functional, Available, Reliable, and Affordable (FARA) equipment developments needed.
3. More research and service projects to promote electronic commerce, resource management, "flexible" agile production, developing commercial products (in DOD contractor facilities).
4. More research in the design for manufacturability in DOD apparel is desirable to reduce differentiation from commercial apparel construction.
5. One on one assistance to small manufacturing enterprises is needed for basic technology assimilation.

## **APPENDICES**

## **APPENDIX A**

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AR890020

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Charles Gilbert Associates, Inc.  
GA880599

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Clark-Schwebel Fiber Glass Corp.  
GA880163

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SC880033  
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PA880025  
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Blue Bell PA 19422 -  
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AL880058  
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GA880603  
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FL890034  
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NC890077

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GA880078

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GA880618

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NC880071

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KY880018

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TN880037

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GA890662

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GA880579

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AL880010



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TX900101  
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Jostens  
SC880027

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GA880202  
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NY880002

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FL890032

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KS880004

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TX900102  
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MD880021  
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KS880005  
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TX880071  
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MS880015  
Hwy #45 S, P.O. Drawer K

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VA890041  
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TN880003

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TN880014  
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GA890657  
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MS880029

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CA880021  
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## **APPENDIX B**

**Samples of *AMTC Quarterly* and *AMTC Tips***

# AMTC QUARTERLY

Apparel Manufacturing Technology Center

Sponsored by the United States Defense Logistics Agency

August 88

## AMTC prepares to occupy new building in Marietta

The flurry of construction activity is almost over as our team prepares to install equipment at the new AMTC demonstration site.

Equipment agreements have been signed with Gerber for its creative designer, computerized marker maker and grader, the S95 computer-driven cutter, and the Gerber Mover. Durkopp has agreed to provide machines for sewing darts, button holes, and fly assemblies. Sunbrand, General Services Data (GSD), and Mr. Engineer will provide software packages for our CIM network. Other agreements with companies such as YKK, Juki, and IBM are pending.

AMTC is a "center within a center," an integral part of the new W. Clair Harris Apparel and Textile Center building on the campus of Southern Tech in Marietta, Georgia.

The 20,000-square-foot facility was made possible by funding recommended by the Georgia Board of Regents and received from the research consortium established by Governor Joe Frank Harris. In addition to AMTC, the building will house four classrooms, five high tech laboratories, and an 80-seat lecture hall.

"This is our opportunity to showcase state-of-the-art apparel and textile manufacturing. Our current students will gain valuable hands-on training. That means a lot to industry today," says Larry

Haddock, operations manager with AMTC and head of the Apparel and Textile Engineering Technology Department at Southern Tech. "We also expect to

attract more students to this very exciting but understaffed field."

Current graduates, added Haddock, receive four to six lucrative job offers each.



*A ribbon-cutting ceremony will mark the grand opening of the W. Clair Harris Apparel and Textile Center on September 26. AMTC's first demonstration is scheduled for October 24-25.*

# The changing face of equipment purchase decisions

Compared to their Japanese and German counterparts, American businesspeople make capital investments at a very low rate. Also, they tend to concentrate on short-term, cost-reduction aspects of equipment purchases at the expense of long-term strategies. The result? A dulled competitive edge. This holds true for the apparel industry as much as any other.

AMTC is pursuing one possible explanation for this approach -- the set of rules by which American executives decide which equipment to invest in.

## How decisions are made

It's easy to see how Americans came to adopt their equipment purchase rules. In the 1950s and 1960s, when discounted cash flow methods were hailed as a way to quantify decision-making, the U.S. was beginning to experience competition from overseas. Lower wages looked like the logical reason for overseas successes. And the solution seemed to be reducing the quantity of American labor to effect parity in wage costs. Thus was born American business' short-term, cost-reduction mindset, at the expense of long-term strategic perspectives.

## Alternative methods

Several researchers have developed alternatives to the traditional discounted cash flow methods. One approach seeks to expand the evaluation criteria to include non-quantifiable aspects in a sort of voting structure. Decision-makers rank equipment attributes in order of importance, then apply weighting factors to them. For example, a high volume plant with a narrow, stable product line might choose the following attributes and weights:

Machine capacity	10
Scrap rate	8
Maintenance required	8
Seam tolerance range	6
Machine set-up time	5

This method is known as Multi-Attribute Decision Analysis, or MADA.

The second alternative seeks to quantify the intangible aspects of equipment. For example, predicting increased market share due to quick response capability is uncertain. However, those familiar with a company's customers can identify a market share range, which can then be used to put some dollar value on the quick response benefit. Proponents argue that it is better "to be approximately right (by including the intangibles) than to

be precisely wrong (by excluding them)."

These methods are especially useful when evaluating difficult equipment decisions where the primary benefits lie in increased flexibility, better quality, and reduced response times to customer orders -- important issues to the apparel manufacturer of today.

## Honing the edge

AMTC is undertaking research to answer the question, "How can the apparel industry best use these new approaches?" The first major task entails a survey of apparel manufacturers to document their decision rules and the types of equipment decisions they make. A preliminary report will summarize the results.

Subsequent research will investigate the application of nontraditional methods to specific equipment and plant situations.

The goal of these studies is to keep that competitive edge sharp.

Bill Riall

## Traditional methods for analyzing equipment investments

**PAYBACK PERIOD**=How long it takes an investment to recoup the initial expenditure. Acceptability is determined by length of payback period.

**Advantage:** Easy to calculate.

**Disadvantage:** Does not consider the time value of money or the impact of positive cash flows once payback has been achieved.

**DISCOUNTED CASH FLOW**=Applying a discount rate to the sum of positive and negative cash flows generated by an investment. *Net Present Value* applies a discount rate (usually the cost of capital) to all flows. A positive sum indicates acceptability. *Internal Rate Of Return* uses the cash flow to calculate what discount rate would yield a net present value of zero. If that discount rate is higher than the cost of capital, the investment is deemed acceptable.

**Advantage:** Offers solutions to the problems of the payback period method in a logical, unassailable framework.

**Disadvantage:** As practiced, does not consider aspects such as quality improvement, manufacturing flexibility, increased business due to better service, and strategic implications.

## Model to describe the manufacturing process

For most people, the word "architecture" connotes structures of brick, steel, and concrete. But in the world of computer software, it refers to the framework of a computer model that simulates real-world events.

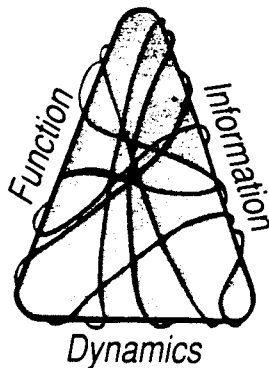
AMTC researchers are looking at developing an architecture, initially for the manufacture of trousers and later for apparel in general. Some of the basic concepts emerged from a U.S. Air Force program aimed at defining "blueprints" for Computer-Integrated Manufacturing (CIM).

A trouser manufacturing environment comprises design, marker making, pattern packing, spreading, cutting, sewing, inspection, pressing, quality control, and marketing, inventory management, finance, and costing. We can look at this environment in three different ways.

### FUNCTION

Each area plays an important role in the manufacturing process by performing a specific function. Defining this function requires a framework composed of the inputs, the outputs, the constraints, and the relationships with other areas.

For example, sewing requires pockets, front and back leg panels, waistbands, and so forth to produce the final pair of trousers. Constraints include operator skill levels, types of machines, and types of stitches. Sewing has a direct relationship with cutting — the parts must be cut before they can be sewn. It has an indirect relationship with design — new designs may require reprogramming some machines.



### INFORMATION

As lifeline for the various functions, information provides another way to model the manufacturing process. For example, sales orders drive production rates, which dictate raw material inventory levels and material cutting schedules.

Other types of information that define the operation may include seam lengths, operator skill levels, market data, and product costs.

### DYNAMICS

Resources and requirements change with time. For example, an operator is out sick, a machine is down, or a material delivery is late. Also, new orders and cancelled orders can impact production requirements.

By modeling the dynamics of the environment, we can enable companies to perform "what if" analyses that are essential to keeping the operation smooth and profitable.

### Benefits

The research on this architecture will enable manufacturers to model their existing plants and analyze the effectiveness of changes that they can make without disrupting current operations and without having to invest heavily in new equipment before the impact can be quantified.

This architecture will remove some of the risk involved in moving toward a more automated industry.

*Sundaresan Jayaraman*

## Other research topics under consideration

The AMTC steering committee recently met with our team to provide guidance on research direction that would be of particular interest to the apparel industry. Topics under consideration include:

- ▲ In-Process Quality Control in Apparel Production
- ▲ Discrete Event Simulation Applied to Apparel Manufacturing
- ▲ Fast, Low-Cost Vision Systems for Flexible Automated Apparel Assembly Stations
- ▲ Automated Flexible Work Cells for Apparel Manufacturing
- ▲ Applicability of Flexible Work Group Methods to Manufacture of Military Utility Trousers
- ▲ Shop Floor Control System for an Apparel Assembly Plant
- ▲ Investigation of Cut-Order Planning Algorithms
- ▲ Sales History Analysis and Production Forecasting/Planning
- ▲ Investigation of Manufacturing Techniques in the Apparel Industry

AMTC researchers will be working closely with individual apparel manufacturers and industry groups. If you want to participate in the program, please call (404) 894-3636.

## Focus meeting fosters interaction between industry and university

How can industry capitalize on significant advances in manufacturing technology research? On September 22-23, 1988, Georgia Tech will host *Energizing the Future: Focus on Textile, Apparel, and Carpet Manufacturing*. The Focus will introduce executives invited from over 200 firms to the missions and operations of five cooperative research centers:

- Apparel Manufacturing Technology Center
- Center for Work Performance Problems
- Computer-Integrated Manufacturing Systems Program
- Manufacturing Research Center
- Material Handling Research Center

Each of these centers takes a multidisciplinary approach to solving problems that affect plant productivity, operating costs, and production response time.

Dr. Fred L. Cook, director of Georgia Tech's School of Textile Engineering, believes that teamwork and partnership between Georgia Tech and industry will further advance the manufacturing capabilities of textile, apparel, and carpet producers.

According to Dr. Cook, "Only through substantial industry and university collaboration can the U.S. regain its ability to compete successfully in world markets."

The AMTC staff can help you learn more about getting involved with the Georgia Tech research centers.

## AMTC steering committee members for 1988-1989

### Defense Personnel Support Center

Col. Victor Fernandez

### Dowling Textile Mfg. Co.

Jea Summers

### Fashion Star, Inc.

Bill Loftin

Andy Cooper

### The Hartwell Co.

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Scott Hall

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### Riverside Mfg. Co.

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### Russell Corporation

Dan Peoples

### Tennessee Apparel Corp.

Ted Helms

### Vanity Fair Mills

Carl Langlois

### Warren Featherbone Co.

Jeff Whalen

### Wilkins Industries, Inc.

John Wilkins

*Be sure to see the **AMTC** display at the Fall '88 Bobbin Show*

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*Premiere Issue*

# AMTC QUARTERLY

Apparel Manufacturing Technology Center  
Sponsored by the United States Defense Logistics Agency

January 89

## AMTC Demonstration a Success

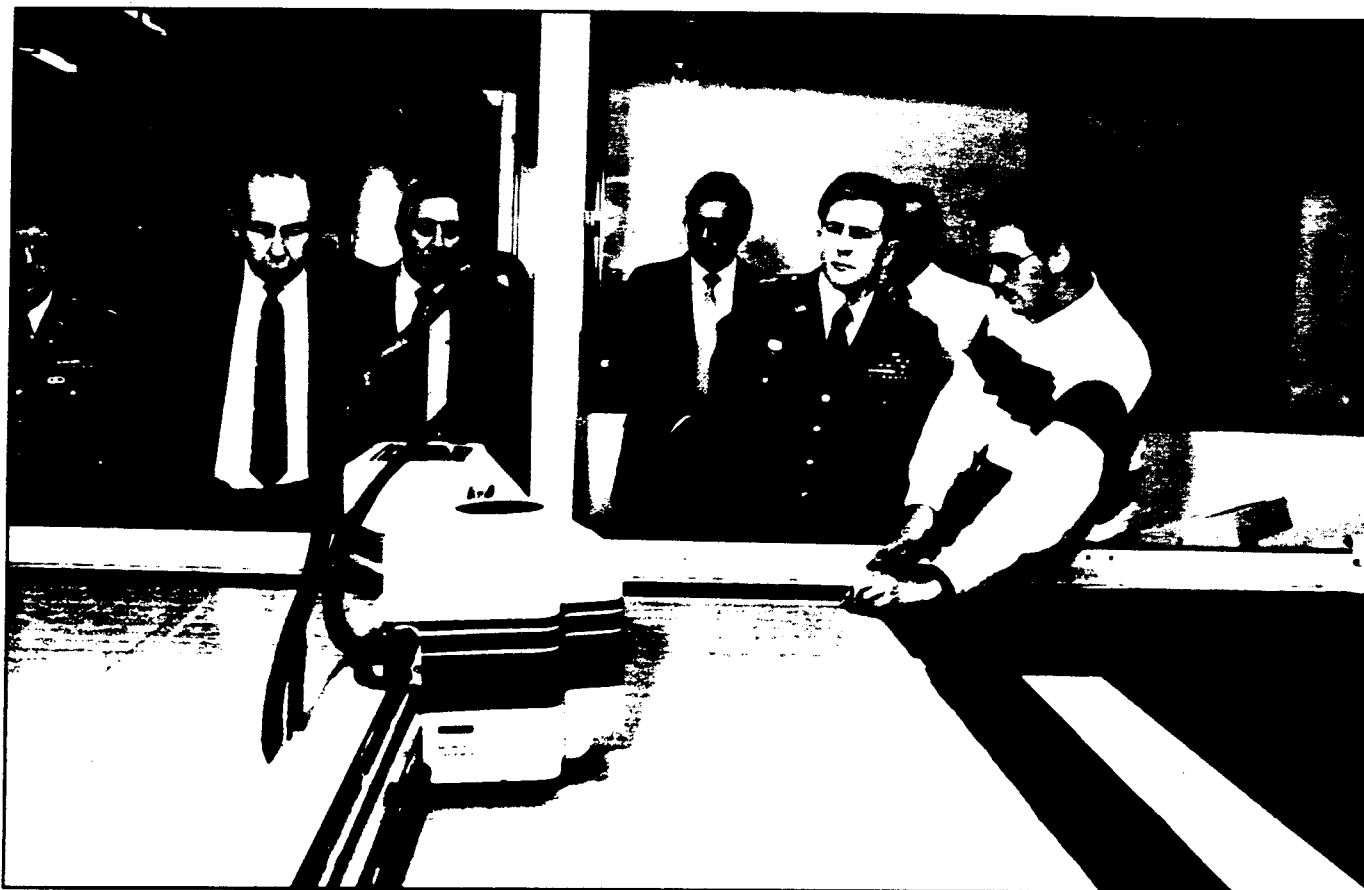


Photo by Gary Meeks

Over 200 manufacturers, suppliers and researchers attended the first major demonstration at the Apparel Manufacturing Technology Center on October 21. The center is located on the Southern Tech campus in

Marietta and is operated jointly by Georgia Tech and the Southern College of Technology under the sponsorship of the U.S. Defense Logistics Agency.

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*A student shows visitors and staff how the Gerber S-95 high-speed cutter automatically spreads then cuts one or two-ply fabric held under vacuum.*



# Modular Manufacturing Workshop to be Offered by AMTC

**D**efense against foreign competition is a major concern of apparel manufacturers. The ability to increase productivity in the U.S. apparel industry would be an important step toward achieving this goal. Flexible manufacturing is a philosophy which has become a highly competitive manufacturing strategy in many industries based on its capability to quickly and efficiently adapt to changes in product mix, demand, and design. This concept promises manufacturers not only increased productivity, but more efficient use of capital equipment, improved project quality and consistency, reduction of work in process, reduced direct labor costs, and reduced floor space requirements. These benefits have been demonstrated in actual production within the apparel arena, as well as in other non-related industries.

The essence of established flexible manufacturing systems is a self-contained grouping of computer-integrated "cells." These cells consist of machines that perform all operations required in the manufacturing of a number of parts with similar processing requirements. In the apparel industry, this technique has been termed modular manufacturing. Instead of automated cells of machines, a flexible work group consists of teams of workers cross-trained in several operations. The emphasis is on group effort and employee involvement, quality at the source, and short throughput time. A natural result of this approach is a decrease in process inventory effort. This decrease is due to just-in-time delivery of components to the cell, and a shift in focus from high individual productivity to quick delivery of the finished product. One research topic to be proposed to DLA will be the further study of flexible work groups within the apparel industry.

This workshop is the first of four to be offered by AMTC in 1989. It will provide the participants with an opportunity to interact with key figures in the apparel industry who have first-hand experience with modular manufacturing. Efforts will be made to bring in not only managers from these companies, but also the team leaders who deal with the daily problems on the shop floor. These individuals will share both positive and negative experiences of actually implementing modular manufacturing, as well as ideas on what will be necessary to make modular manufacturing a reality in the apparel industry. Issues to be addressed include:

- worker attitudes
- responsibility for quality control
- managing work in process inventory within the work group
- how management can best deal with employee involvement in decision making on the shop floor.

For a complete listing of the AMTC workshops refer to the calendar listing below. If you would like additional information concerning the Flexible Manufacturing workshop please call John Adams, (404) 894-3636.

## AMTC Calendar Listing

**February 1-2** – Second Major Demonstration at AMTC

**\*Spring '89** – Modular Work Groups – Flexible Manufacturing

**April 29** – TECHFEST - Southern Tech - General Public Invited

**\*Summer '89** – Unit Production Systems

**\*Dates To Be Announced**

## RESEARCH UPDATE

### Apparel Architecture Project

**A** preliminary version of the functional model of apparel manufacturing first described in the AMTC Quarterly, Aug. '88, is expected to be completed by the end of January. The functional model, developed using the IDEF methodology, describes the various functions in apparel manufacturing in varying levels of detail. Researchers are seeking the participation of experts from the industry and academia for reviewing the draft model. The input received from the experts will be used to modify the model and develop a standardized representation of the apparel manufacturing process. This model can be used by the companies for evaluating their current operations with a view to making improvements and enhancing productivity.

For more information contact Dr. Sundaresan Jayaraman, Principal Investigator, Apparel Architecture Project, at the School of Textile Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.

1. Model to Describe the Manufacturing Process - AMTC Quarterly, Aug. '88.
2. Jayaraman, S., "Design and Development of an Architecture for Computer-Integrated Manufacturing in the Apparel Industry", Technical Report, AMTC, Georgia Tech, Atlanta, Georgia 30332, July 1988.

# "The Customer Is Always Right"

By John C. Adams  
AMTC Director

In a recent examination of the state of the domestic textile/apparel industry I noticed several striking, sometimes alarming, points. Most observers will agree that the domestic textile/apparel industry is in a crisis situation. It accounts for \$20 billion of the U.S. trade deficit, second only to the automobile industry. Wages of U.S. apparel workers are approximately 55 percent of the average U.S. industrial workers' wages. Still, a significant advantage exists for the foreign producers with average wages in Latin America and the Pacific basin being about \$1 per hour, and in China approximately 20 cents per hour! But wage differentials and competition from imports is not the only aspect of the issue.

Traditionally, the apparel industry has taken a product-oriented rather than a marketing-oriented approach to its business. However, if one subscribes to the old adage that "the customer is always right," and a belief that customer demand dictates the direction of any industry, then marketing-oriented concepts such as flexible manufacturing and quick response should be considered.

For example, consider the time it takes for a garment line to move from fiber production through retail. This is often as much as 65 weeks, of which approximately 12 weeks are spent in actual production with the balance of time related to inventory. Such a long period does not allow manufacturers and retailers to respond to rapidly changing markets. Contributing to this, is the fact that the average sewing operator spends almost 80 percent of his/her time handling and positioning garment pieces resulting in only 20 percent actual construction time!

Beyond that, and perhaps more importantly, is the fact that companies frequently fail to correctly identify their market segments. A business cannot adequately recognize its competitors or its opportunities if it too narrowly defines its span of operation or services. For example, if a retailer owns a trucking business he is actually part of the transportation industry. Likewise an owner of video rentals is part of the entertainment industry not just the video rental segment. By applying this philosophy, we can view the textile/apparel industry as incorporating not only clothing but home furnishings and industrial products as well. A business must see itself as a link between the producer and consumer of goods and services.

A textile/apparel industrialist which views himself as a link in the clothing industry instead of simply a producer of certain goods, is anticipating new market opportunities to arise. Consider the position of a retailer entering a new season. His ideal position is to have a small inventory of certain items and maximize his variety of goods. To do this successfully, he must be able to restock quickly as the item sells, minimizing stock-outs. Items that do not sell within a

prescribed time would be reduced in price until they sell (forced price reduction), making space available for other items. The ideal apparel manufacturer would use flexible manufacturing, computer generated manufacturing and quick response (QR) techniques. For this approach to be successful the textile/fabric producer must also utilize these techniques.

Retailers such as Wal-Mart, Macy's, and J.C. Penney are experimenting with these manufacturing approaches. Textile World, Nov. '88, published results of a recent study conducted by the J.C. Penney Company involving sixty garment types - half were sourced domestically; half imported. Results are dramatic:

- Sales increased 35-45 percent for quick response (QR) fashion and 20-25 percent for QR basic products compared to non-QR goods.
- Inventory turns were 7.1 percent for QR fashion goods, 5.1 percent for QR basics and 3.8 percent for non-QR goods.
- Operating costs were 14.9 percent of sales for QR fashion products compared to 16.8 percent for QR basics and 20.4 percent for non-QR goods.
- QR fashion products generated a 9.6 percent net return on sales; QR basics, 7.2 percent and non-QR, 4.0 percent.

David Miller, president of J.C. Penney states, "We know quick response works and we are expanding it as rapidly as we can."

Suppliers must implement the necessary technology and techniques to supply these services or step aside and let other suppliers who have defined their business broadly to assume this market. After all, it is our goal to serve the customer and in the final analysis the customer is always right.

I welcome your comments.

**Editor's Note:** Please send your suggestions, questions and/or comments to:

John Adams, AMTC Director  
Room 209 O'Keefe Building  
GTRI/EDL Georgia Tech  
Atlanta, GA 30332



# Chair Design Criteria for Employee Workstations

A well-designed chair will help maximize operator productivity while reducing the incidence of lower-back-related health problems. In general, a workstation chair should meet all of the following criteria:

1. The chair should have five legs for structural stability. It should be on casters if the operator stands and sits or frequently moves about at the workstation. If workers must place or obtain materials to or from their side, the chair should swivel to prevent upper body twisting.
2. The height of the chair seat should be adjustable, usually between 15 inches and 21 inches for sitting tasks. For alternate sit/stand workstations, the chair height should be compatible with the height of the work surfaces, such that the relationship between the upper body and the two work heights stays the same. Footrests should also be provided. They should have a nonskid surface, be 12 inches to 16 inches long, and slope 30 degrees or less.
3. The seat cushion should conform to the following criteria:
  - The seat cushion should be firm, but not hard, and preferably of some non-slip fabric type material. This will help reduce the buildup of body moisture.
  - The seat cushion should be slightly hollowed (i.e., concave).
  - The front edge of the seat cushion should curve downward. This facilitates good blood circulation to the feet because it eliminates the pressure point on the underside of the thighs.
  - The seat cushion should be about 18 inches across and 16 inches from front to rear (plus or minus one inch).
- The seat cushion should usually be horizontal. However, adjustable backward tilts of zero to eight degrees have proven beneficial in shifting the body's weight against the backrest.
4. The backrest should be between 13 inches and 18 inches wide and easily adjustable between four inches and nine inches above the seat cushion. If the backrest is nonadjustable, it should start no higher than four inches above the seat cushion and extend about 18 inches up.
5. For primarily physical work tasks, armrests should be carefully evaluated because they tend to restrict the natural movement of the arms. For primarily nonphysical work tasks, the armrests should be at least 19 inches apart, nine inches above the seat cushion, and about three inches wide (plus or minus one half inch).
6. The user of the chair should be instructed on how to adjust the chair. Ideally, no tools should be required to make adjustments, so that each operator can easily find the optimal position through trial and error.
7. Finally, no single chair is optimal for all work tasks. The chair's design should be matched to the overall functional design of the workstation and to the tasks being performed at the workstation.

Robert Wayne Atkins, P.E.  
AMTC Tip

Industrial Engineering Technology Faculty  
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# AMTC QUARTERLY

Apparel Manufacturing Technology Center  
Sponsored by the United States Defense Logistics Agency

May 89

*AMTC's first research project, **Design & Development of an Apparel Manufacturing Architecture**, has been underway for over nine months. In this special issue of the Quarterly, the project's researchers describe the progress made to date. Six other research endeavors are in progress and will be featured in future issues.*

To develop an effective architecture, researchers sought an industry partner to participate in the project. Oxford Slacks of Monroe, Georgia, offered to join forces with AMTC. Through Oxford's support and substantial contributions, the function model was formulated.

Melissa Bailey, Oxford Slacks' Divisional Production Planning Manager, believes that the joint research effort has been rewarding for both parties. According to Ms. Bailey, "The architecture project has been very interesting, and Oxford is pleased to play a role in AMTC's activities."

## Apparel Manufacturing Architecture: The Function Model

by Sundaresan Jayaraman and  
Rajeev Malhotra  
Georgia Institute of Technology  
School of Textile Engineering

### Introduction

In its efforts to become more competitive, the textile/apparel industry is concentrating on adopting hi-tech concepts such as Computer-Aided Manufacturing (CAM) [3]. CAM entails the effective utilization of computer technology in the management, control, and operations of the manufacturing facility through direct or indirect computer interface with a company's physical and human resources [1]. Computer-Integrated Manufacturing

(CIM) involves the use of computers for the integration of the various operations of an apparel enterprise (see Figure 1):

- Fashion and Product Design
- Marketing and Sales
- Merchandising
- Production Planning
- Materials Requirement Planning (MRP)
- Manufacturing
- Materials Handling
- Quality Control
- Administration
- Financial and Business Management

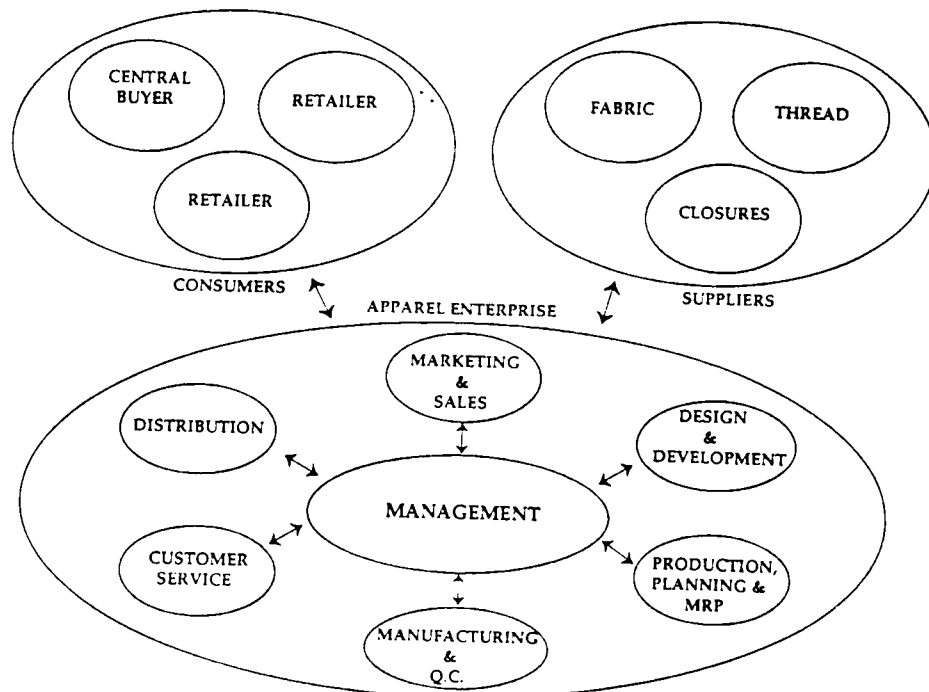
Here, the terms CIM and CAM are used interchangeably.

An important prerequisite for successfully implementing CIM in the apparel industry is a fundamental study and analysis of the three major facets of the enterprise: function, information, and dynamics [2]. (See IDEF Methodology box for an explanation of the three facets.) Such a definition of the enterprise is known as the architecture.

## AN ARCHITECTURAL APPROACH TO CIM

The word architecture connotes a coherent and solid structure based on a strong foundation and embodies a goal-oriented design strategy. More specifically, an architecture for apparel manufacturing denotes a framework for the representation and analysis of the enterprise. Because it will serve as a blueprint for implementing CIM in the apparel industry, the architecture should be developed first.

## NETWORKING AN APPAREL ENTERPRISE



Both the architecture and the process of developing the architecture provide several benefits to the apparel industry, including:

- Improved Operational Awareness
- Evaluation of Current Practices
- Development Basis for Cost-Benefit Analysis in Investment Decisions
- Definition of Standards for Data Communications between Machines and Systems

### **Organizational Awareness**

Analyzing an apparel enterprise can be educational for the analyst and for company personnel. The result of the activity is a model (or document) that clearly describes the system as it exists at a specific time. This AS IS model quickly reveals areas that can be improved with very few resources, e.g., bottlenecks in the flow of information and production, duplication and overlapping of efforts, and inefficient organizational structures and reporting procedures. Thus, the model contributes to an overall awareness of the organization's various operations.

### **A Communication Vehicle for the Organization**

Any extensive analysis of an operation will not be complete (and the original objectives realized) unless the results can be communicated to management for appropriate action. Suggestions on modifications and enhancements cannot be made (and subsequently implemented)

unless management clearly understands the existing operation. Because a uniform representation methodology is used in developing the AS IS model, it can effectively fulfill the role of a communication vehicle.

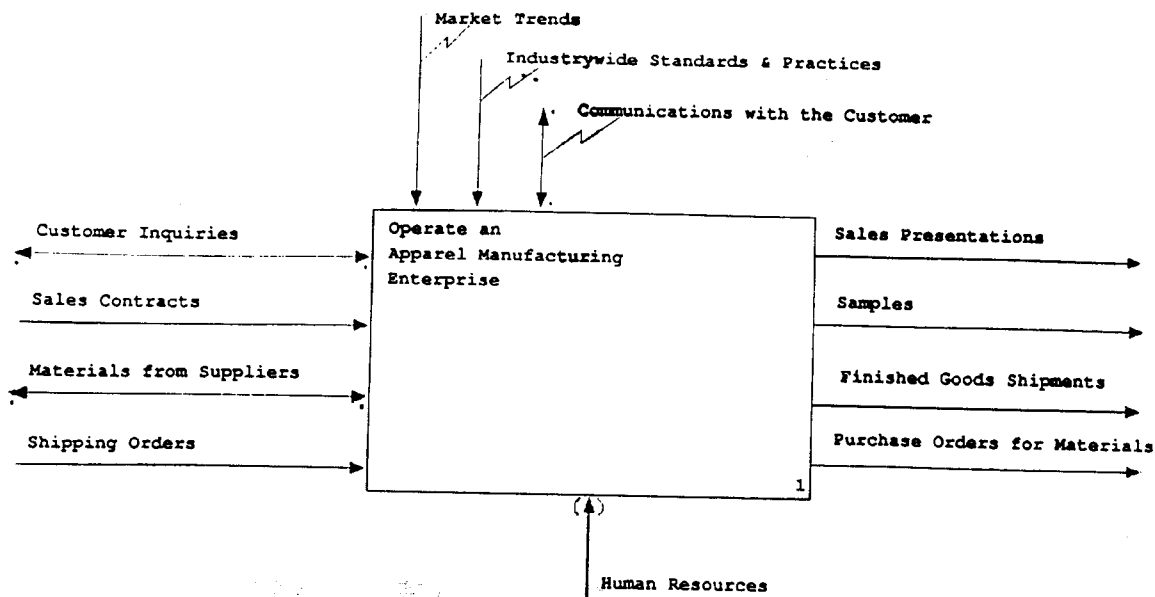
### **Basis for Cost-Benefit Analysis**

The rapid pace of technological developments is generating a wide array of equipment and automated systems for the apparel industry. However, extensive cost-benefit analysis should precede the deployment of technology in any organization. The AS IS model will serve as the basis for evaluating proposed enhancements to the operation prior to their incorporation. This minimizes the risk in capital investment decisions and ensures a better utilization of scarce resources. This model subsequently can be used as a reference to assess the current state of the enterprise and determine if original objectives have been met.

### **Defining Standards for Equipment and Information Exchange**

As with any other manufacturing industry, the apparel industry is characterized by islands of automation. For example, Computer-Aided Design (CAD) systems design the product, whereas NC machines cut the fabric. However, no standards exist for transferring data from CAD systems of one vendor to NC cutting machines of another vendor [7].

## The A-0 Diagram: Operate an Apparel Enterprise Function



1 VIEWPOINT: Managers responsible for day-to-day operations of the enterprise.

2 PURPOSE: Develop the functional specification for a CIM system for an apparel manufacturing enterprise.

Figure 2.

## The A0 Diagram: The Six Major Functions in the Apparel Enterprise

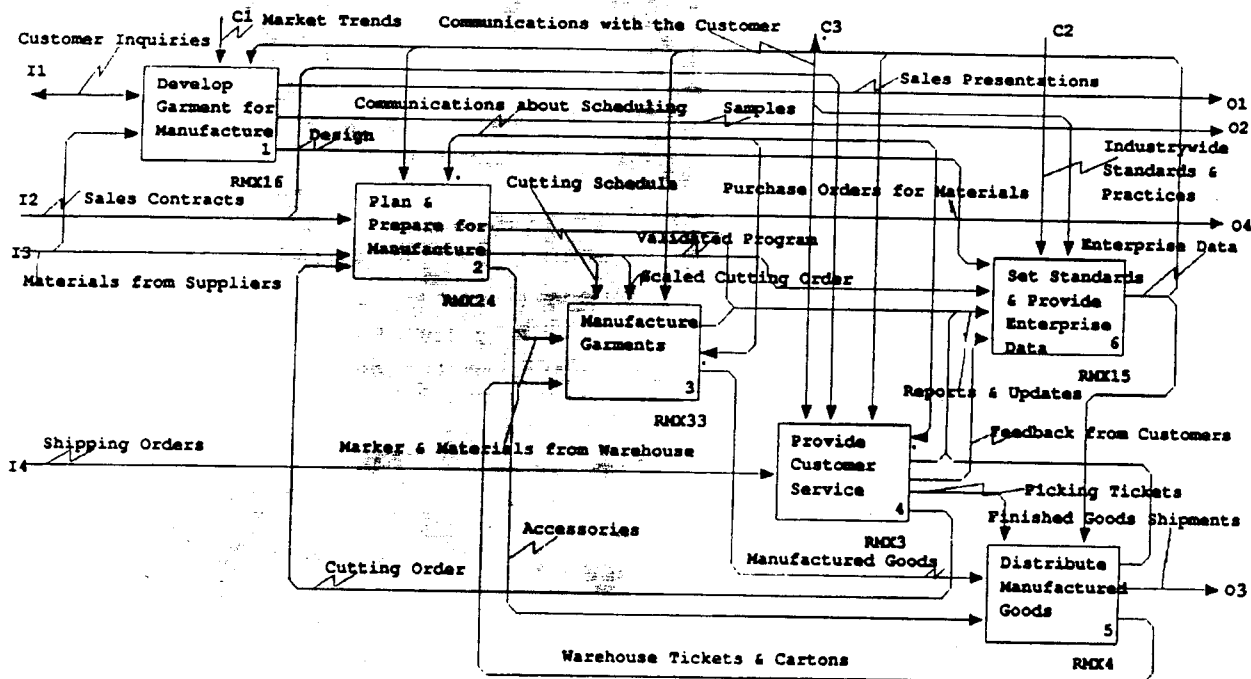
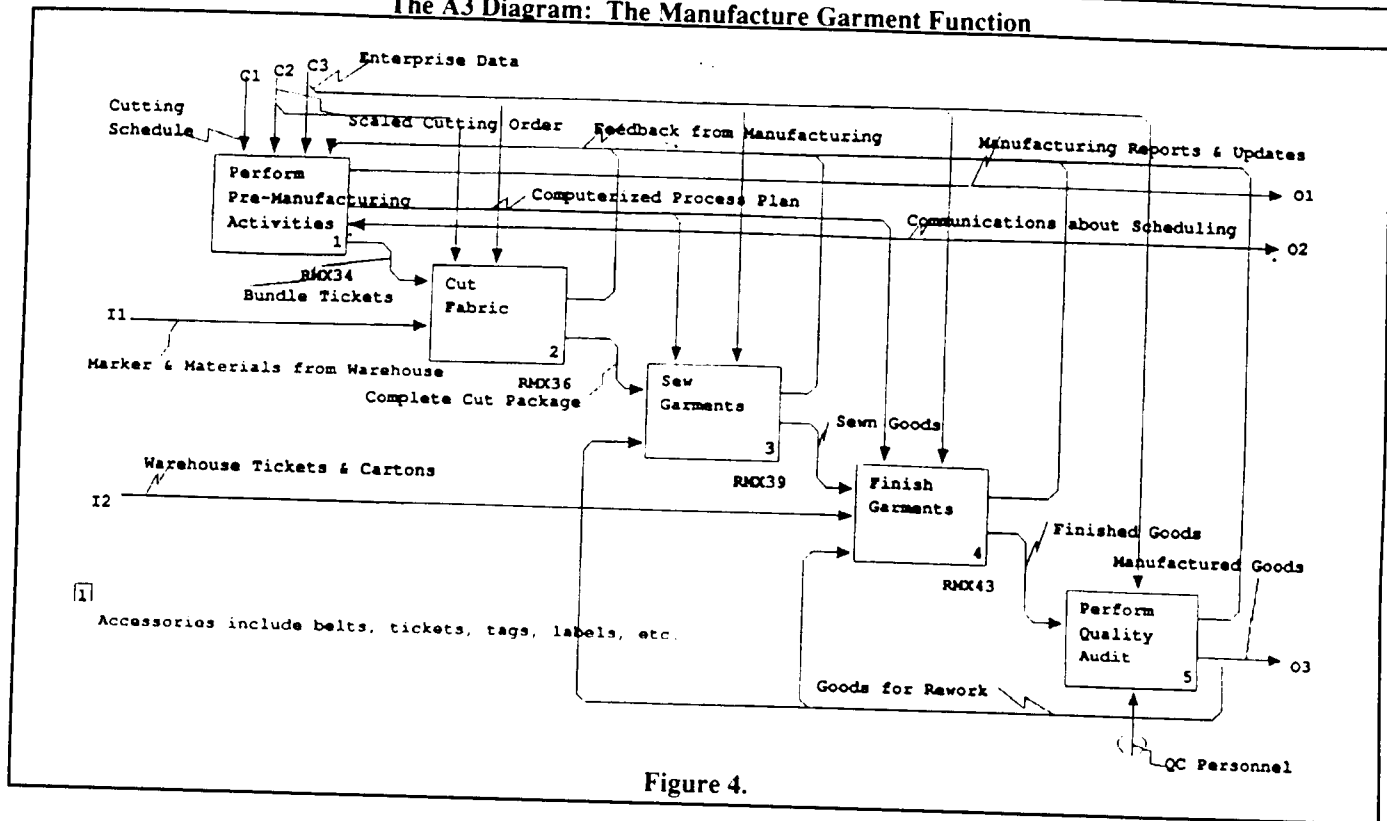


Figure 3.

To begin effectively implementing CIM, firms should build bridges between the islands. However, this is not feasible unless the firm clearly understands the various functions carried out in each of the islands and the required informa-

tion flow between them. An advantage of Apparel Manufacturing Architecture (AMA) is the resulting comprehension of the functions and information. This means the firm can develop specifications and standards to ensure seamless

**The A3 Diagram: The Manufacture Garment Function**



**Figure 4.**

integration in the apparel enterprise, even among machines from different equipment vendors.

## DEVELOPMENT OF THE FUNCTION MODEL: RESEARCH METHODOLOGY

Trouser manufacturing has been chosen as the initial target for developing the AMA. Once the Trouser Manufacturing Architecture (TMA) is developed, its scope will be expanded to include other garments. The IDEF methodology was selected to develop the architecture [3]. (See IDEF Methodology box for details on the methodology.)

The authors recognized the importance of working in close collaboration with the apparel industry and sought to identify at least one industry partner for the initial phase of the research. The approach was to develop a model based on interactions with a specific organization, have the model reviewed by a broader cross-section of the industry, and suitably refine the model, thus creating a generic model of the trouser manufacturing enterprise. Oxford Slacks, a member of the AMTC Steering Committee, has provided the necessary support to develop the AS IS model.

### The Modeling Process

The first step in the modeling process is to understand and appreciate the various functions in the apparel enterprise. The authors held regular meetings with managers of the different departments at Oxford Slacks, the discussions

beginning with an overview of the firm, then covering each department's functions (as shown in Figure 1). Typically, these functions were discussed in terms of inputs, outputs, constraints, and the mechanisms involved. Interactions with other departments and the information flow were also discussed, along with potential areas of computerization. After the meeting, a written summary was submitted to the manager for review. The manager's comments were incorporated into the report. Concurrently, the development of the IDEF function model for each of the departments was carried out using Wisdom Systems' IDEFine® software on an IBM® PC/AT machine.

During the modeling process, the Oxford team discovered that in a few functions, existing procedures contained duplication of efforts by various departments. This modeling exercise enabled the team to modify these conditions, thereby improving organizational efficiency.

The AS IS function model was presented to Oxford Slacks for review. Based on the company's comments, the model has been refined. The TO BE model is currently being developed.

### The Function Model of Apparel Manufacturing

The A-0 diagram in Figure 2 shows the entire scope of the system being described, *i.e.*, operating an apparel manufacturing enterprise. It establishes the subject (*context*, in IDEF terminology) of the model and forms the basis for further decomposition or breakdown of activities. It is created from the *viewpoint* of managers responsible for

day-to-day operations. Its *purpose* is to develop a functional specification of the enterprise for designing a CIM system.

The *inputs* to the enterprise are denoted by the arrows to the left of the box. The enterprise receives inquiries from the customer on new products, designs, and styles, and responds to the requests (hence the double-headed arrow with the dots). It receives sales contracts and shipping orders from the customer while materials (*e.g.*, fabric and trim) are received from suppliers. The operation of the enterprise is constrained or governed by market trends, industry standards and practices, and customer requirements. The resources or *mechanisms* responsible for the operation are humans and machines. The tunnels “()” around the *mechanism* arrow imply that the details of the *mechanism* are not important at the next lower level. The *outputs* from the enterprise consist of sales presentations, samples and shipment of finished goods to the customer, and purchase orders issued to suppliers for materials.

## The A0 Diagram

The A0 diagram is further described in Figure 3. The A0 diagram clearly identifies the six major functions performed daily. Because it provides a complete description of the model (including the interactions between the various functions), the A0 diagram is commonly referred to as the top-level diagram. All the *inputs*, *outputs*, *constraints*, and *mechanisms* on the A-0 diagram are seen in the A0 diagram.

The first function (the first box) is to develop the garment for manufacturing, and it is based on customer needs and market trends. There is a great deal of interaction between the enterprise and the customer during product development, a fact denoted by the double-headed (feedback) arrow. Materials should be procured from suppliers to produce samples. The other results (*outputs*) of this activity are garment designs and sales presentations to customers.

Once the customer places an order, the next function is to plan and prepare for manufacture, as represented by the second box in the A0 diagram. This activity can be performed only if sales contracts have been finalized and the availability of materials ensured. It is constrained by the customer's delivery requirements. The *outputs* of this activity include the issuance of the cutting schedule, purchase orders for materials, and markers and materials from warehouse.

The third box represents the manufacturing function which encompasses cutting, sewing, finishing, and garment inspection. It requires markers, materials, warehouse tickets, and cartons as *inputs* and is constrained by the cutting schedule and the size/color distribution. The major *output* of this activity is the manufactured garment.

Providing customer service is the other major function performed in an apparel enterprise, and this is represented by the fourth box in the A0 diagram. The Customer Service Group is responsible for interacting with the

The A32 Diagram: The Cut Fabric Function

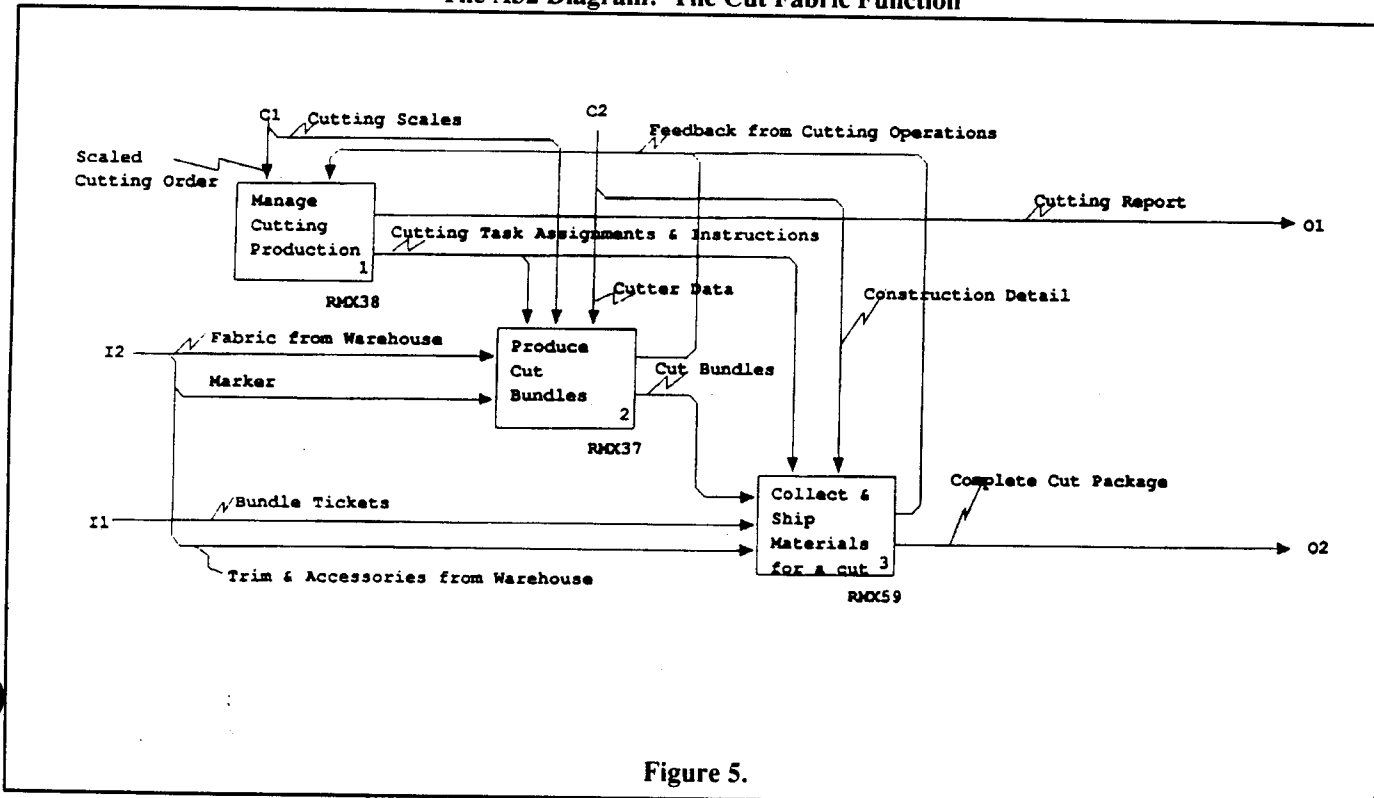


Figure 5.



### The A322 Diagram: Produce Cut Bundles Function

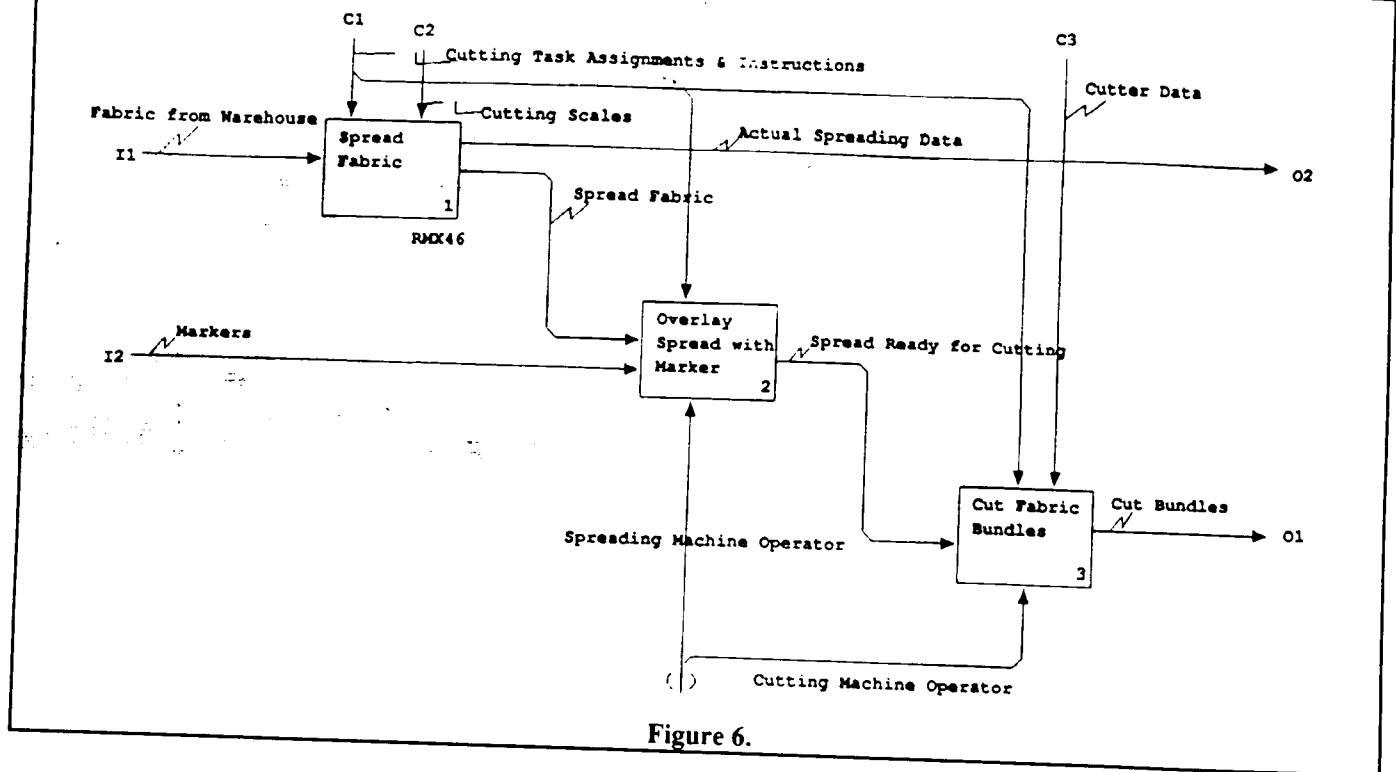


Figure 6.

customer on various matters related to an order: confirmation, tracking, resolution of problems (e.g., delivery, quality). Because this group interacts closely with the customer, it is responsible for issuing the final order to cut which serves as the input to the Plan-and-Prepare-for-Manufacture function. It also issues the shipping instructions for the finished goods.

Another major function involves distribution of finished goods, as represented by the fifth box in the A0 diagram. This function is constrained by the shipping instructions issued by the Provide-Customer-Service function.

Information about the various functions is vital for efficient operation of the enterprise. Consequently, every function generates information on its performance (e.g., production data, quality problems) as one of its outputs. This information should be monitored and utilized for setting standards and providing data for the enterprise's operation. This function, represented by the sixth box in the A0 diagram, plays a key role in the successful operation of the enterprise. It is constrained by industry standards and practices in wages, engineering, and quality.

Because the model represents the viewpoint of the managers responsible for the various functions, the *mechanisms* are not shown in the figure. They appear only at the lowest level in the function hierarchy.

### Zooming in on the Manufacture — Garment Function

The A0 diagram provides only a bird's-eye view of the major functions. Each of the functions in the A0 diagram can be analyzed along similar lines to the degree of detail desired. The Manufacture-Garment function in the A0 diagram will be expanded to illustrate this methodology.

Figure 4 shows the breakdown of the Manufacture-Garment function into the five functions used to manufacture the garment. This is known as the A3 diagram because it corresponds to the third box in the A0 diagram. The *inputs, constraints, mechanism, and outputs* in this diagram are inherited from the A0 diagram. Thus, the Manufacture-Garment function in the A0 diagram can be thought of as the parent for the various functions in the A3 diagram. Note that the mechanism, QC personnel, is shown in the Perform-Quality-Audit function (the fifth box) because it (the function) has not been broken down further.

Moving one level down in the hierarchy, the Cut-Fabric function in the A3 diagram has been expanded into the component functions (or children) as shown in Figure 5. This is known as the A32 diagram because it corresponds to the second box in the A3 diagram. The *input I1* (Marker & Materials from Warehouse) in the A3 diagram has been broken down into Fabric, Marker, Trim and Accessories in the A32 diagram, thus providing more information on the

### The A3221 Diagram: Spread - Fabric Function

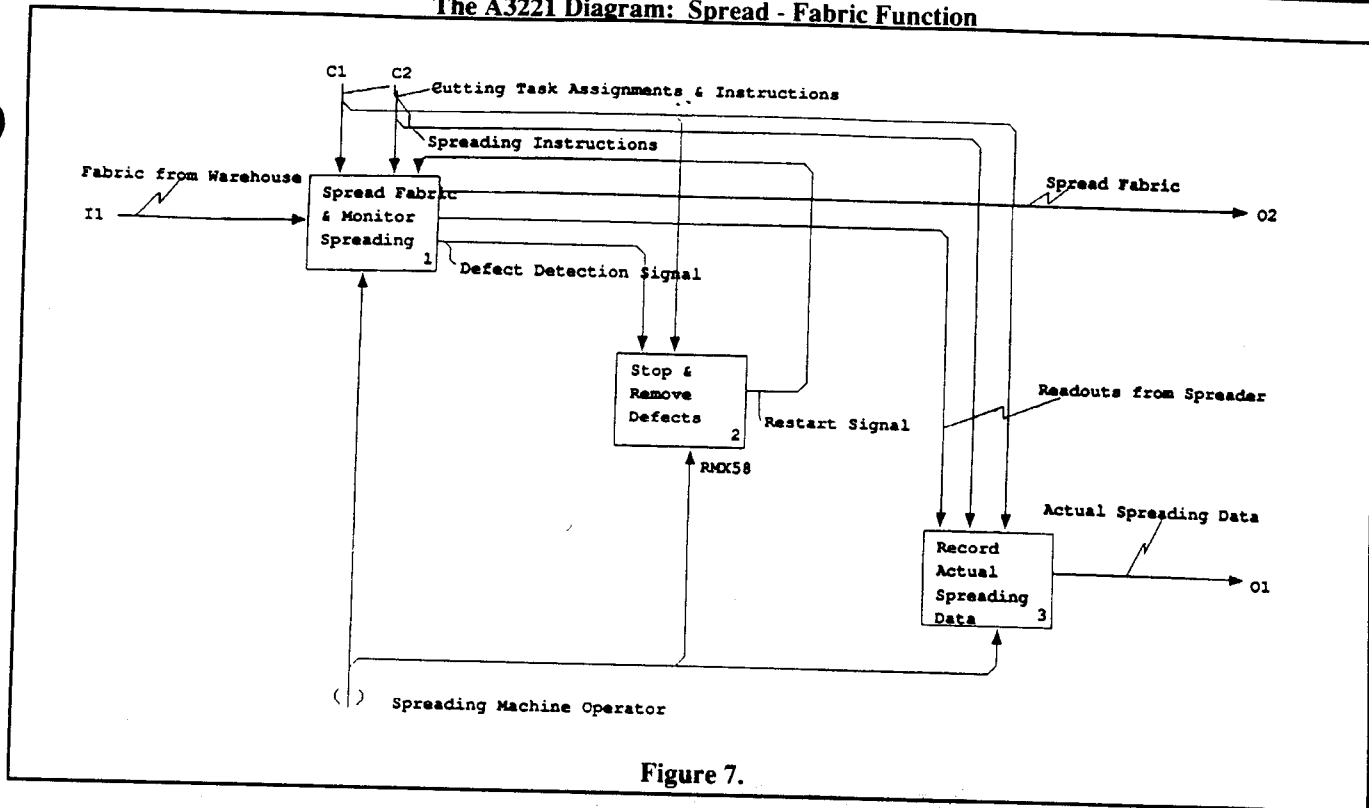


Figure 7.

### The A32212 Diagram: Stop & Remove Defects Function

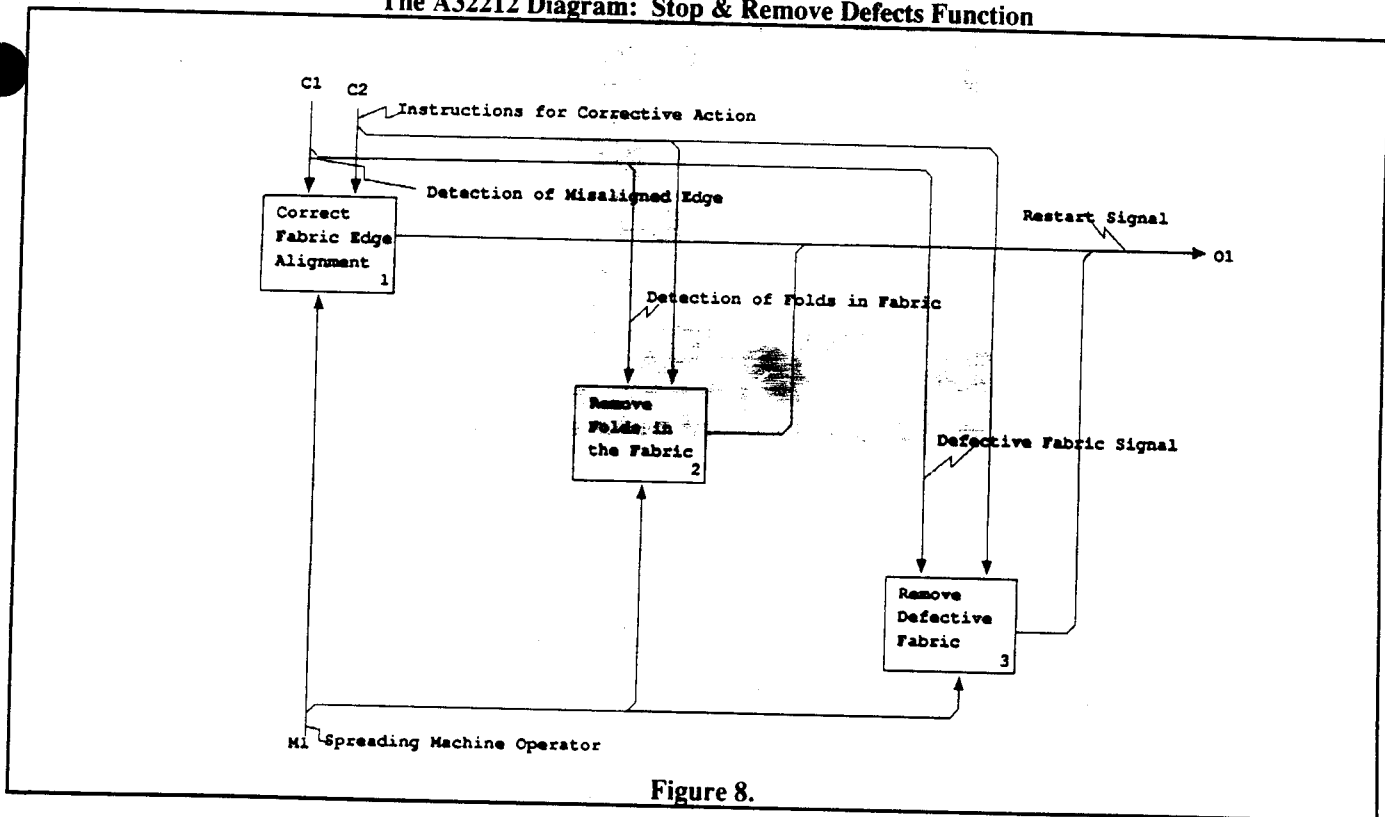


Figure 8.

process. Also, the *outputs* — Cutting Report and Complete Cut Package — in the A32 diagram correspond to the *outputs* of the Cut-Fabric function in the A3 diagram. The same is true of the *constraints* C1 and C2.

Figure 6 shows the expansion of the Produce-Cut-Bundles function into its component functions. This is known as the A322 diagram because it corresponds to the second box in the A32 diagram. Likewise, the further

expansion of the Spread-Fabric function is shown in Figure 7 as the A3221 diagram. Finally, the expansion of the Stop-&-Remove-Defects function is shown in the A32212 diagram in Figure 8. This diagram clearly shows the various functions performed in removing defects in the fabric during the spreading operation.

Thus, the modeling process involves hierarchically breaking down the higher-level functions to the desired degree of detail. The lower the function in the hierarchy, the more detailed the information on the function. This modeling process resembles problem-solving: breaking the problem down into sub-problems and solving the individual sub-problems to obtain the overall solution.

Breaking down all the major functions to the desired degree of detail leads to the function architecture for the apparel manufacturing enterprise.

## FUTURE PLANS AND DEVELOPMENTS

The function model is being refined based on input from members of the AMTC Steering Committee and other interested groups in the apparel industry, including members of the AAMA CIM/COM Committee. The next step in this research involves development of the information model.

## Acknowledgements

This work is being carried out under a research grant from the U.S. Defense Logistics Agency (DLA-900-87-D-0018). The authors acknowledge the efforts of DLA officials Mr. Don O'Brien, Mr. Dan Gearing, and Ms. Helen Kerlin for making this endeavor possible.

*AMTC wishes to thank the following individuals for the long hours and valuable assistance they have contributed to the project.*

### Oxford Slacks Research Team AMA Project

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Charles Hamm	Donna Ruark
Jerry Harney	Jim Seignious
Wilbur Holloman	Ed Upchurch
Larry Johnson	Jack Valentine

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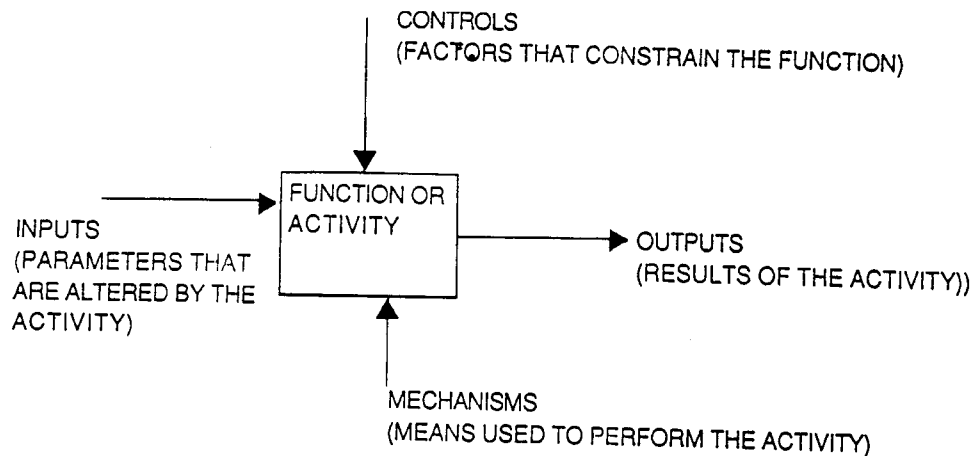
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## The IDEF Methodology

The U.S. Air Force established the Integrated Computer-Aided Manufacturing (ICAM) program in the 1970s to increase manufacturing productivity through the systematic application of computer technology [6]. From this program emerged the IDEF (ICAM DEFinition) method comprising three modeling methodologies which graphically characterize manufacturing: IDEF<sub>0</sub>, the Function Architecture; IDEF<sub>1</sub>X, the Information Architecture, and IDEF<sub>2</sub>, the Dynamics Architecture.

IDEF<sub>0</sub> is used to produce a function model which is a structured representation of the functions of a manufacturing system or environment, and of the information and objects which interrelate those functions. IDEF<sub>1</sub>X is used to produce an information model which represents the structure of information needed to support the functions of a manufacturing environment. IDEF<sub>2</sub> is used to produce a dynamics model which represents the time-varying behavior of functions, information, and resources of a manufacturing system. Together, these three architectures of manufacturing serve as blueprints for CIM.

## The IDEF0 Methodology



### IDEF 0 METHODOLOGY

REPRESENT FUNCTION WITH (IN) BOXES

REPRESENT MATERIALS, SYSTEMS, OUTPUTS AND INPUTS WITH ARROWS

INTERRELATIONSHIPS BETWEEN COMPONENT PARTS ARE DRAWN/REPRESENTED

Figure 9.

**IDEF<sub>0</sub>:** The Function Model provides a description of manufacturing in terms of a hierarchy of functions. It establishes a structure for gathering data aimed at understanding the manufacturing environment to the desired degree of detail. The model serves as the basis for the next stage of the architecture development process. Each function is represented in a box and the *inputs*, *controls*, *outputs* and *mechanisms* associated with the function are drawn as arrows (see Figure 9). The position at which the arrow enters a box conveys the specific role of the interface.

Associated with a function model is the *context* that establishes the subject of the model, while the *viewpoint* determines what can be "seen" within the *context* and from what "slant." The *purpose* establishes the intent of the model, *i.e.*, the goal of communication it serves. The boxes are numbered according to their position in the hierarchy. The numbers begin with the letter A (for Activity or function) and the *context* diagram has the number A-0 (A minus zero). The *context* diagram is broken down into the A0 diagram and the boxes in the A0 diagram are numbered consecutively beginning with 1, *i.e.*, A1, A2, etc. When the A1 box (function) is subdivided, the boxes are numbered A11, A12, A13, and so on.

To ensure usefulness and clarity, the methodology suggests that if a function cannot be subdivided into three lower-level component functions, then the division should not occur. Additionally, a particular diagram in a model should not have more than six lower-level function boxes. This is known as the 3-6 rule. The IDEF<sub>0</sub> models do not

indicate precedence sequences or flows. The arrows do not signify any passage of time.

**Software:** Several software programs for building the function and information models for AMA (Apparel Manufacturing Architecture) are available. The criteria for software selection have been discussed elsewhere [3]. Based on these criteria, Wizdom Systems' IDEFine software has been selected and used in the development of the function model. It runs under MS-DOS on the IBM PC/AT system.

### About the Authors

*Dr. Sundaresan Jayaraman*, Assistant Professor in the School of Textile Engineering, is the Principal Investigator on the Apparel Architecture Project.

*Mr. Rajeev Malhotra*, is a graduate research assistant working toward his Ph.D. in the School of Textile Engineering.

For more information on the project, or participation in the review of the function model, please contact Dr. Jayaraman at 404/894-2490.

# Unit Production Systems

by Charlotte Jacobs-Blecha

## Introduction and Background

Many forces are precipitating an urgent need for changes in apparel manufacturing, specifically in marketing requirements, labor force, and manufacturing alternatives. One manufacturing alternative receiving considerable attention is the unit production system (UPS).

The initial concept for the unit production system originated in the 1940s with the straight-line work-flow system. In this system, the production unit was a single garment assembled in sequence as it passed from one operation to another. A series of chutes allowed the rapid movement of a unit from one operation to the next, sometimes with conveyors to facilitate the movement.

Although this system permitted very quick throughput times, it is rarely used now due to its extreme inflexibility. Given fixed chutes or conveyors to move production units through the assembly process, even a minor product change

entails shutting down the whole system to reconfigure a new sequence of operations. Because the work-in-process levels between operations are very low, the throughput rate of the line system is necessarily paced by the most difficult operation or the slowest operator, making it difficult to offer incentives to faster workers.

## The Unit Production System

The UPS consists of an overhead transporter or conveyor—today, coupled with computerized control and management reporting systems. As with the old line system, the production unit is one garment as opposed to bundles of cut parts to be assembled into many garments. Hangers or clamps carrying the garment components automatically come to the operator so that many operations can be performed without removing the work from the hanger. After sewing, the operator sends an electronic signal to the UPS that the work is finished and ready to progress to the next work station.

The modern UPS is attracting so much attention because of the need for a short manufacturing time, and because the application of computer technology drives overhead conveyor systems, and allows real-time information for management control to be assembled.

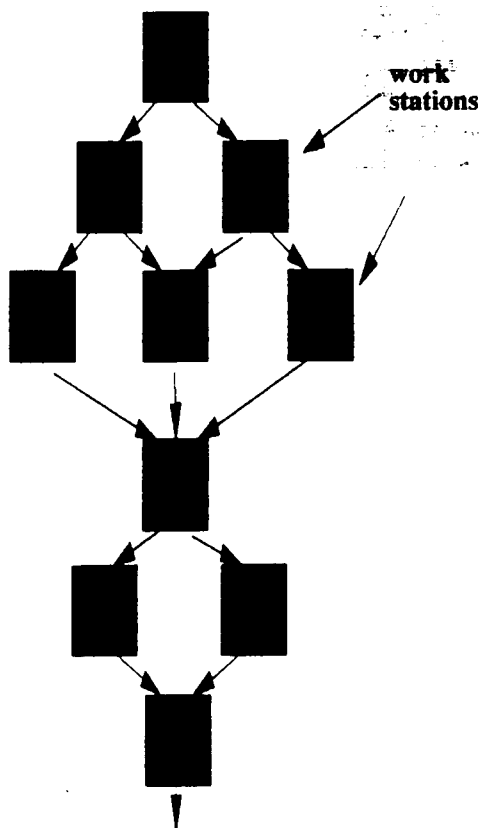
The application of computer technology in real time is improving the control of the UPS. Time backlogging allows better tracking of inventory at each work station and work can be routed to the lowest backlog. Also, because operations are interdependent, garments can be routed non-sequentially to operations low in work. The use of overflow stations provides a way of balancing the system when excess work-in-process accumulates. The use of accelerated real-time decision-making lets the supervisor test alternative balancing decisions and hence improve the quality of the decisions.

## Advantages and Disadvantages of the UPS

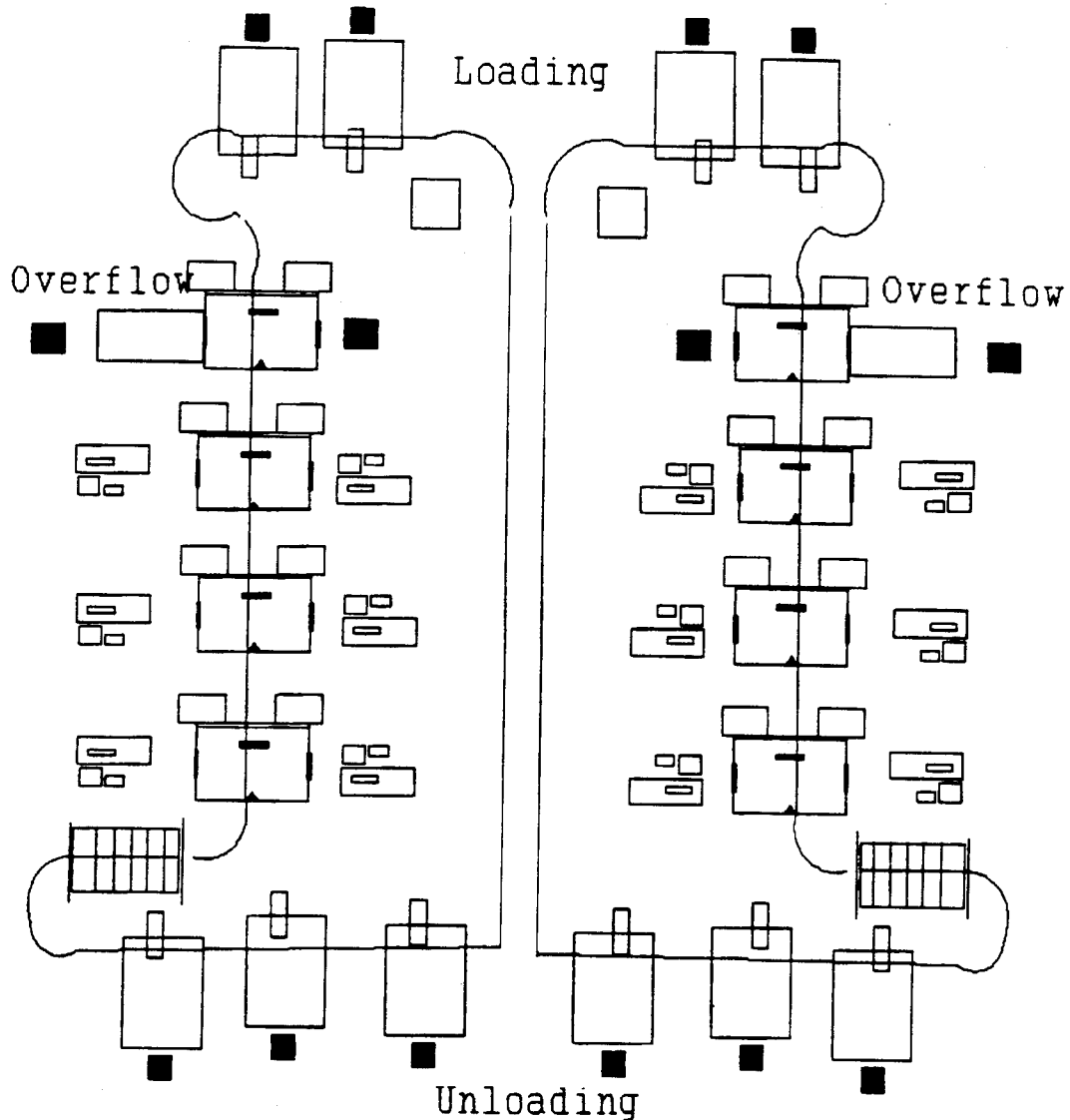
The primary advantages of the UPS are (1) short throughput times which can equal or exceed those offered by the old line system, (2) the elimination of bundle handling and clerical time, (3) computerized payroll and production data, and (4) low inventories. Another advantage is the capability of automatically sorting matchable items (tops and bottoms), eliminating later delays.

The UPS in the sewing room can reduce labor costs 15 percent to 40 percent. There is no bundle help required and the work flow can be better controlled by supervision. The UPS can reduce throughput time from weeks to days or from days to hours, including planning and sorting time.

### LINE SYSTEM



## UNIT PRODUCTION SYSTEM



The UPS requires a high capital investment. Costs for each work station can exceed \$3,000, so costs for an entire UPS with many work stations can easily exceed \$100,000. However, reduced inventory carrying costs can allow the system to recover its costs fairly quickly.

Work flow and balance must be carefully managed, otherwise the entire system can grind to a screeching halt. Also, spare machinery must be on hand. Since there is so little work-in-process, machine delays can be fatal to successful operation. Frequent job changing is often required to keep the work flow moving smoothly, indicating that cross-training of operators is virtually a necessity.

Similarly, absenteeism must be controlled or compensated for with supplementary operators and/or cross-training.

The fixed configuration of the UPS is a somewhat limiting factor in its flexibility. Also, the installation of the system requires dedicated floor space. However, the reduced space required for low work-in-process levels may actually more than compensate for the additional space required for the system. Finally, it is clear from the above discussion that UPS technology requires disciplined management. This, too, may prove a plus because more discipline usually means better control.

## The Future

UPS systems are just one strategic method for increasing productivity in apparel manufacturing. However, it should still be considered an emerging technology. Not all installations of UPS systems have been success stories, although many companies have seen drastic improvements within days of the start-up of full-scale operation of a UPS. Regardless of whether the UPS prevails in the future of flexible manufacturing for the apparel industry, the innovative thinking and utilization of computer technology is appropriate and necessary for the revitalization of the enterprise. □

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## Modular Group Presentation Experiences "Real-World" Problems



Wilder/Ella Street

Last October, the Apparel Manufacturing Technology Center's pilot plant took on a new product, the camp short, and a new concept, modular manufacturing.

For several months, technicians at the center have studied real-world modular work groups and deliberated on the best implementation scheme for AMTC. The camp short was selected because of its manufacturing simplicity and its compatibility with AMTC's original product, the Navy utility denim trouser. Programmable cutting, bundle sub-assembly, and unit production final assembly are still used to manufacture the trousers. A separate modular area has been established for sub-assembly of the camp short.

The concept was first demonstrated October 11 at AMTC's Modular Manufacturing Workshop. Participants watched a "start-up" modular group experience some common problems of real-world modular manufacturing, such as unbalanced work flow and lack of sufficient operator cross-training.

The modular group ran a total of 12 hours on October 10 and 11. Work flow began to smooth out after eight hours, but constant supervision was required. To increase the group's flexibility, AMTC employed the advanced technology equipment in figure 1.

*continued on page 3*

*Left: Dale Reichman, a sophomore at Southern Tech, is busy topstitching pocket flaps with the new programmable tacker*



## Exploring the Human Factor in Apparel Manufacturing

Apparel manufacturing in both conventional and advanced environments is a highly labor-intensive enterprise. The productivity and profitability of a plant is closely related to the efficiency, morale, and safety of its individual employees. Workplaces, jobs and equipment should be designed to promote these factors.

Ergonomics, *the systematic study of the physical and mental characteristics and limitations of workers and the design of jobs and equipment while taking these human factors into account*, has been effectively applied in a host of working environments. Transportation, health care, mining, and textile manufacturing are just a few of the industries that have received benefits of research and development in ergonomics. However, the practice of ergonomics or human factors engineering has not been extensively applied in the apparel manufacturing workplace.

To address this issue the Georgia Tech Research Institute is conducting an ergonomics project under the direction of David Ortiz (Economic Development Division) and Michael Kelly (Systems Engineering Laboratory). Their project explores ergonomic problems in conventional and advanced apparel manufacturing workplaces.

Recently, the GTRI team visited three apparel plants representing a range of sizes and degrees of automation. In each, researchers identified problem jobs based on employee complaints, absenteeism, turnover, or unusually difficult job requirements.

Over 130 employees, mostly representing the "target" jobs, took part in anonymous interviews about their jobs, workstations, training, and any physical discomfort they might experience while working. Detailed physical measurements were taken of these employees. Noise, temperature, and illumination levels at selected workstations in each plant were also

recorded. Videotapes of employees performing the targeted jobs were made for detailed task and motion analysis.

### *Measurement of Worker Dimensions*

Careful design of workplace tools and equipment to "fit" the operator requires an engineer to utilize data on the relevant physical dimensions of the worker population.

Georgia Tech researchers measured 123 female sewing operators for the following:

- standing and sitting height
- eye, shoulder, elbow, and knee height
- arm reach
- thigh thickness
- hand length and width

Results indicated that the existing data bases on the dimensions of civilian females provide an adequate description of this group, although sewing operators may be slightly larger than the civilian norms.

### *Physical Discomfort*

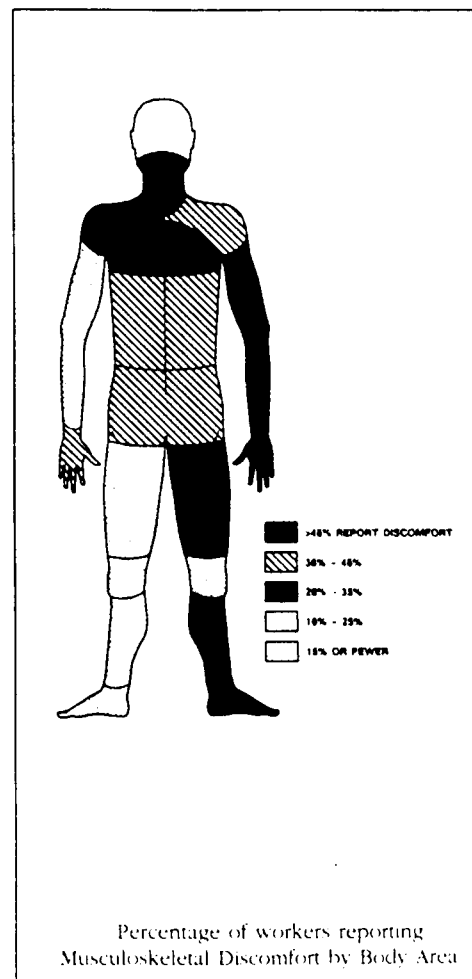
Improper job design and badly designed workplaces often can create aches and pains in the muscles and joints of assembly workers. Discomfort can result from awkward working postures, excessive reaches to obtain or dispose of work, excessive manual manipulation of parts, unusual strength or endurance requirements, or combinations of these factors.

The GTRI study discovered the most common areas of pain to be in the neck and upper back. These pains are probably related to a stooped working posture adopted by a majority of the seated workers in response to the visually demanding nature of the work as well as the design of the seated workstations.

Operators in jobs requiring rapid, repetitive manual manipulations of materials also reported high degrees of pain or numbness in their hands. These symptoms suggest that apparel workers

may suffer from carpal tunnel syndrome, a disease of the median nerve of the wrist and hand that is characterized by such pain and numbness.

An interesting finding was that older, more experienced workers reported lower levels of musculoskeletal discomfort than did the younger, less experienced workers. Physical complaints were at their peak in workers at approximately 30 years of age and steadily decreased to their lowest point in workers over 60 years of age. This finding may be attributed to a reluctance on the part of older workers to complain, to a change in their perception of discomfort, or to workers who are susceptible to musculoskeletal discomfort leaving the



## Modular Group *continued from page 1*

sewing workforce at a relatively young age. The average age of sewing operators taking part in the interviews was slightly over 40 years

### Training

In all three plants visited, initial operator training was strictly on-the-job practice. Training consisted of brief demonstrations by a supervisor, the chance to try the operation through a few cycles under close supervision, and infrequent subsequent feedback. Because of the complex skills required for the jobs, periods as long as 17 weeks were allowed for trainees to "get up to speed" to make the prescribed rate. Typically, in the more complex jobs, performance continued to improve for many months after the initial training period.

### Future Work

During future phases of the program, the GTRI staff will implement and gauge the effectiveness of several minor ergonomic improvements in conventional sewing workplaces. Research will then identify and address ergonomic difficulties in the advanced manufacturing workplace. Finally, a set of reference and training materials will be produced to help the apparel manufacturing manager or floor supervisor identify and solve typical ergonomic problems without resorting to outside consultation.

For Further Information concerning this project, please contact  
Michael Kelly 404/894-8240  
Dan Ortiz 404/894-3806  
Georgia Tech Research Institute  
Atlanta, Georgia 30332

Station	Equipment	Operation
1	Brother BAS 325	Sew and topstitch back pocket
2	Reece 46 003	Pockett welt and attach flaps
3	Mitsubishi LT2 250	Hem pocket and sew to panel
4	Brother BAS 350	Topstitch front pocket
5	Wilcox & Gibbs 500-4	Sew seams (w/PROFEEL Zippy)
6	Union Special 63900M	Hem Shorts

**Figure 1**

The flow of production is from the programmable cutter to the existing jeans line (fly operations) to the module (front and back sub-assembly) to the unit production system (waistbands, beltloops, ticketing, tacking, final inspection, and folding).

To attach both front and back pockets, AMTC uses a quick response approach which eliminates custom clamping. The Brother programmable sewing machine is programmed to stitch two different styles of pocket flaps for the camp short. Using the machine's temporary clamps and a plexiglass plate, two different flap styles can be sewn and top-stitched with changeover time under one minute.

At Station #4, another innovative step eliminates the pocket pre-creasing operation and special machine clamps. At Station #3 the patch front pockets are hemmed and attached to the front panel. Then, at Station #4, the panel and pocket are placed in a non-customized, open clamp and topstitched. This process eliminates the need for pre-creasing of the pocket and a special clamp for each different pocket style. Changeover time between pocket styles has been reduced to less than a minute using this process.

In the modular work group, operator efficiency is monitored by the ProSystem Work Group Performance

Unit. This system, manufactured by Eildon, tells the group it's real-time production efficiency and recalculates efficiency with each completed unit.

The October demonstration marks the beginning for modular manufacturing at AMTC. The modular group will experiment with new equipment and innovations during the coming months, making it an integral part of the center.

Future plans for the module include the application of real-time data collection using the ACS/Redifacts system and development of computer-directed sewing stations where both operator and machine receive instructions from a computer network.

If you would like to receive additional information on AMTC's modular work group or if you want to schedule a demonstration, please call Dale Stewart or Jim Young at (404) 528-3177.

## AMTC Student Views



### James Cage

Graduate Student — Georgia Institute of Technology.

Major — Working on Master's degree in Management Science.  
Holds BSEE from Georgia Tech.

Certificates — Computer Integrated Manufacturing

Future Plan — To pursue a career in manufacturing engineering and manufacturing management.

**Q** How did you come to work with AMTC?

**A** Previously, I worked for a year on GTRI's *Industrial Advisor*, a newsletter for Georgia business and industry. I joined the AMTC project because it provides exactly the kind of help I think the apparel industry can use—assistance with understanding and implementing new manufacturing technology and management techniques.

**Q** What type of responsibilities do you have? Do they utilize your academic background/interests?

**A** The AMTC project gives me a "real-world" view of the concepts I'm studying. I've worked directly with industry, learning how companies organize their plants and manufacture garments, and I've written database software here to help organize our efforts to communicate with industry.

AMTC also lets me bring concepts and knowledge from my classes to the project. My academic experience with computer hardware and software and my knowledge of concepts such as flexible manufacturing systems and computer integrated manufacturing have all been utilized by the AMTC project. It's a great blend of practical technology, research, and communication.

**Q** Describe your efforts with the marker making project.

**A** So far, my main responsibilities have been recruiting vendors of existing systems to participate in the project and reviewing literature on the underlying mathematics of raw material utilization. I'm working closely with Dr. Charlotte Jacobs-Blecha, who created the project, and I'm learning a great deal about abstract research and the effort necessary to keep a project like this running.

Our next step is to study existing systems, both from the perspective of the vendor and the companies using them. I'm preparing a survey for the companies to determine how efficient, costly, and automatic their systems are.

**Q** Do you feel that participation in this research will help you in your career? How?

**A** Most definitely. My work on the marker making project is only the latest experience AMTC has given me on planning, organizing, and executing a project. Through my work with the computers here and on the publications we produce for the apparel industry, I've added to my programming and communications skills. Most importantly, the project has given me an appreciation of the impact that new methods and technology can have on an industry.

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# A-M-T-C

Q U A R T E R L Y

## 50 Years on the Job at Tennessee Apparel

*Florence Harper has spent more than 50 years at Tennessee Apparel. She feels good about the company and the company feels the same about her. This article looks at Florence and some of the things that Tennessee Apparel does to retain loyal employees like Florence.*

Florence Harper believes that being a sewing machine operator is a worthwhile occupation. "If I was 18 today, I'd come here to work — it's still a good job for young people today." And after more than 50 years at Tennessee Apparel in Tullahoma, Tennessee, Florence isn't planning on quitting, either.

Instead, she works four days a week making belt loops because "I like the people." And her fellow employees evidently like Florence, too. Last year at the annual picnic, she was showered with gifts designed to show appreciation of her long-term commitment to the company. Among the items received were 50 red carnations, 50 silver dollars, 50 diet Cokes (her favorite drink), and 50 free meals at her favorite restaurant. All of these were presented under a huge banner that read "Florence Harper Day — 50 Years of Service."

Tennessee Apparel now boasts three plants, more than 500 employees, and equipment that could make other firms envious. Competitors might also envy the apparel company's ability to attract and keep loyal employees. Florence is not the first to put in 50 years of service at Tennessee Apparel. Novella Waller reached that milestone in 1970, and 12 other employees currently have over 30 years of service. And, according to Personnel Manager



**After 50 years, Florence Harper still belts them out. Among her other achievements, she has sewn more than 150 million belt loops.**

Carol Davis, a significant percentage of employees leave only to come back and reapply for their old jobs.

That helps to explain Florence's advice to new workers: "No matter where you go, it won't get any better than here." When asked what makes her stay, Florence explains that satisfying relationships with supervisors and co-workers, good working conditions, Christmas bonuses, attendance awards, and job security are important factors.

Before she underwent open-heart surgery, Florence approached Vice President for Operations Ted Helms about safeguarding her position. Ted replied, "Of course, it wouldn't look right without you here."

According to President John Nicholson, better working conditions and better earnings potential enable this manufacturer of military uniforms to attract and retain a loyal workforce. "One of the things we can sell is that we're running items without a lot of fabric and style changes so it's easier to maintain your earnings," he notes. But more important, when changes are introduced, earnings are protected through guarantees that allow workers time to get up-to-speed on new equipment or new fabrics and styles.

For example, when the company purchased a Gerber cutter, management was not sure it would be an improvement for quite a while. In fact, management was willing to risk some financial losses for a limited time before the machine actually paid for itself in increased productivity. Greater precision in cutting, of course, can increase the productivity of sewing machine operators by reducing rework.

"You have to sell employees on new equipment before it's even installed," Nicholson explains. "We install new equipment on a trial basis

*continued on page 5*

## Ergonomic Workshop Review

Last May 16, 77 people gathered in Atlanta for AMTC's seminar, "Ergonomic Considerations in the Apparel Workplace." The purpose of this session was to provide attendees with a diverse set of viewpoints and experiences about ergonomics in the apparel industry.

### Opening Session

The seminar began with a presentation by Jan Braunstein, director of Peachtree Physical Therapy in Atlanta. She discussed the symptoms and treatments associated with common cumulative trauma disorders (CTDs), and presented an in-depth discussion of carpal tunnel syndrome (CTS). Key points for the apparel industry include:

- CTS victims are generally female between the ages of 42 and 60.
- Many of these sufferers are highly productive employees who fear being labeled a "problem" and delay seeking treatment for tendonitis until it becomes full-blown CTS.
- CTS is often a bilateral illness, which means that the disorder may occur in both arms.
- Treatment of tendonitis is short-term and inexpensive. Remedies for CTS can involve long-term therapy with expenses that far exceed those required for treatment of tendonitis. Jan emphasized the importance of *early* intervention and prevention strategies to improve worker health and safety.

Dan Ortiz, AMTC's ergonomics program manager, discussed various intervention strategies which Georgia Tech recommends to reduce the occurrence of CTDs. He stressed the importance of medical evaluation of new employees, ergonomic evaluation

of repetitive motion jobs, modification of work methods and work stations where appropriate, and operator training programs to educate workers in proper work methods and preventive techniques.

### Case Studies

Three apparel firms were represented at the seminar, sharing aspects of their ergonomics programs. All speakers emphasized that jobs and workplaces must be designed to promote employee productivity and comfort, and to prevent CTDs before they ever occur.

#### Levi Strauss

Art Hill, Levi Strauss' ergonomics manager, and Olin Dunn, manager of the company's Blue Ridge, Georgia, plant, discussed the high points of their ergonomics program. Attendees viewed a 10-minute videotape used to educate new employees and retrain experienced operators at all Levi Strauss facilities.

In all ergonomic endeavors, Levi Strauss emphasizes teamwork among managers and operators. Olin Dunn described one of the most popular programs at Blue Ridge: morning exercise. A certified physical therapist helped the company develop a "work-out," a three-minute exercise period led by the plant manager. This program is so popular that operators requested to incorporate it into Saturday work days, too.

The Blue Ridge plant concentrated its efforts to modify a department which experienced a high rate of workers' compensation claims and injuries. Equipment on Levi's cording operation was redesigned to reduce the ergonomic problems. By working with the

operators, company managers found that the standing position was more comfortable than sitting. Olin Dunn and his management team continued interactions with employees until all the kinks were worked out.

The Blue Ridge plant also installed ergonomic chairs at all of its sitting operations. Based on this success, chairs are being installed in other Levi Strauss facilities.

#### Tennessee Apparel

Diane Smith, engineer technician at Tennessee Apparel, and Ted Courtney, AMTC ergonomist, presented results from the ergonomics research project at Tennessee Apparel Company. During the past 12 months, this firm has participated in several on-site research projects in Tullahoma. The first project involved the company as part of an ergonomics assessment of the conventional trouser manufacturing industry. Results of the study highlighted work station design pitfalls, assessed repetitive motion exposure, and produced a contemporary anthropometric data base of female apparel workers.

As a part of its continuing evaluation of work station design aspects that influence worker comfort and safety, Tennessee Apparel participated in the second project: an in-depth study of the effects of ergonomic chairs in the workplace. Twelve operators volunteered for this study which evaluated the Ajusto Aflex chair against a common work chair. The results indicated improvements in operator comfort and posture with the use of the ergonomic chair. The volunteer operators are already sold on these chairs, and other employees frequently ask management when they will be furnished with an Ajusto chair.

## Intercontinental Branded Apparel

Pete Ehlinger, senior vice president of Human Resources at Intercontinental Branded Apparel (IBA), recommended a seven-step action plan for implementing an ergonomics program:

1. Learn about CTDs.
2. Track CTDs in your operation.
3. Train your people.
4. Treat symptoms early.
5. Implement ergonomic improvements in the workplace.
6. Consider administrative controls.
7. Control losses.

He advised that repetitive motion is only one of the contributing factors to CTS and other cumulative trauma disorders. Ergonomic evaluations must also look at awkward positioning and force or pressure associated with the job.

IBA has instituted a number of ergonomic changes at its Buffalo plant. Adjustable iron stands, automated parts stackers, redesigned weaver workstations, redesigned handtools, and ergonomically designed operator chairs are some of the equipment-related investments made to improve worker comfort.

Pete Ehlinger believes that management's interest in employees' physical well-being has resulted in other benefits for IBA. The company found that employees generally feel better about management when it demonstrates concern for its human resources.

## OSHA'S Initiatives

Suzanne Nash, manager in OSHA's Atlanta regional office, discussed her organization's initiatives in the apparel industry. A few citations for ergonomic hazards have been

issued, all classified as violations of the general duty clause. Suzanne informed the group that OSHA does not have an ergonomics standard in place, but is working on formulating one.

## ACTWU Involvement

Eric Frumin, ergonomics director for the Amalgamated Clothing and Textile Workers Union (ACTWU), discussed his organization's involvement in the ergonomics arena. The ACTWU publishes a worker's guide entitled "Stop the Pain!" to educate its members on preventive techniques for stress and strain injuries. It also suggests ways employees and employers can identify and prevent injuries.

Eric pointed out that there are other industries pioneering solutions for repetitive motion disorders. For example, in 1988 the Motor Vehicle and Car Bodies industry topped the list of industries with the most reported cases of repetitive motion disorders, followed closely by the meatpacking industry. Apparel did not appear on the high incidence list; however, reported cases for the industry increased 403 percent between 1984 and 1989. Apparel firms may benefit from the improvements attained in other manufacturing sectors.

## Conclusion

Clearly, ergonomics is a hot topic in the apparel industry. No one has all the answers, but many firms are taking a close look to determine what ergonomic improvements work best for them. AMTC is dedicated to continue its efforts in the application of this science in the apparel industry.

## COMING IN OCTOBER: ERGONOMIC CONFERENCE

Auburn University will host a 3-day conference on **Control and Prevention of Repetitive Motion Trauma in the Textile/ Apparel Fiber Industries.**

The program will be held October 23-25, 1990, at the Auburn University Hotel and Conference Center. AMTC's Dan Ortiz will be a speaker at the conference. For more information, contact:

J. Fred O'Brien, Director  
Engineering Extension Service  
107 Ramsey Hall  
Auburn University, Alabama  
36849-5331

**(205) 844-4370**

## New Director, New Directions

There's a new hand at the helm of AMTC's demonstration center. Bill Cameron, formerly with Kurt Salmon Associates, came aboard in early April. He plans to pick up the pace of practical demonstrations and encourages more industry participation.

"We're committed to increasing the number of demonstrations," says Cameron. "We were doing one per quarter, but now we may run 13 before the end of the year."

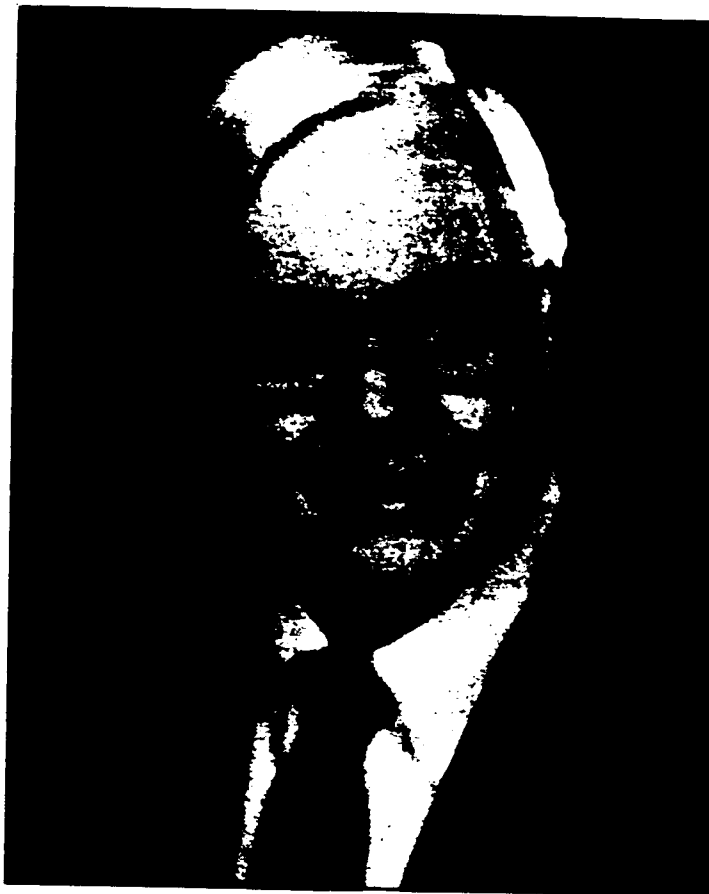
The added demonstrations mean more focus on particular features of the center's advanced equipment and concepts, such as the automatic fly machine and the robot to load it, ergonomic chairs and sewing tables, and the modular manufacturing unit.

The majority of past demonstrations have been rather general, observes Cameron, and the center typically has decided what to demonstrate. But there's room for input and customization. "If an industry group wants to request something and we have the capability, we will do it."

"Industry interest has been good," notes Cameron, "but we need to get the word out more. I don't look at AMTC as a regionalized center," he says, adding with a smile that it is the westernmost of the three DLA apparel centers. "But most industry visitors do come from the Southeast."

Cameron knew about AMTC from his acquaintance with Larry Haddock, serving on the AAMA education committee with him. "I liked Southern Tech and its apparel program. I saw this as an opportunity to get closer to it and I jumped at it. And I'm most enthusiastic about the state-of-the-art equipment and systems we have here."

A graduate of Auburn University, Cameron worked for KSA for more than 32 years as an industrial engineering consultant, a trainer of new consultants, and a course developer. His client list reads like a Who's Who in



apparel—Levi Strauss, West Point Pepperell, Hartmarx, Columbus Mills, and Campus Sportswear. He will continue to teach at Southern Tech, delivering jointly with KSA a three-day plant managers course and five-day engineering course.

He feels the biggest challenge facing him and the center is continuing to innovate, to add more systems and equipment, to help break new ground. "For example, we have a computer-controlled programmable stitcher and we're working with the supplier to sew three styles of pockets without physically changing the machine." It will tie into the CIM network, he explains, which will change the program when the style changes, a concept that

also could apply to collars or cuffs. "It may be another year before we can tie into the CIM network," says Cameron.

The center doesn't do dry runs per se, he says, but minor demonstrations serve that purpose for larger ones to come. Also, one of the technicians continuously trains students to run the equipment. There are three experienced operators, but students provide most of the labor, which, he observes, is a tremendous advantage for the students and the school.

The main purpose of the center is to persuade companies to modernize their factories to be more competitive. Following the adage that a picture is worth a thousand words, it's more convincing to see the equipment and systems in operation than to read or hear about them.

To that end, Cameron accents accessibility. "We encourage readers to look for scheduled demonstrations in this newsletter and in future announcements. Feel free to come by and see us at any time. The unit is not something we want to hide."

-Lincoln Bates

*Tennessee Apparel*  
Continued from page 1

and always solicit feedback from those who will be using it. The groundwork has to be laid, and you need experts on hand when it's first installed to show how the workers and the company will benefit. Payback is not the only thing to consider with automation."

To illustrate this idea, Nicholson points out an unexpected savings. When the company installed an Eton unit production system (UPS) in 1985, its insurance rates fell because bundles were no longer handled manually.

Another surprise arose when the Eton was first introduced. Management discovered that some operators could perform their tasks faster than the UPS was able to deliver work-in-process. These jobs (e.g., hook-and-eye assembly) were promptly removed from the system. In fact, the transition to full operation of the UPS lasted 18 months and required considerable fine-tuning by teams of managers and operators working together.

During her half century at Tennessee Apparel, Florence Harper has seen numerous pieces of new equipment installed in the plant. She notes that many times, employees don't like the new automated equipment. "But after they get used to it, they come to like it," she says.

Florence Harper may spend another 50 years at Tennessee Apparel. "It's a good place to work," she says with a smile, "kind of like home."

-Claudia Huff

## **AMTC UPCOMING EVENTS - 1990**

### **AUGUST 6 - 10**

5-day course for engineers

### **AUGUST 23**

AMTC Annual Contract Briefing

### **AUGUST 23 - 25**

3-day course for plant managers

### **OCTOBER 15 - 19**

5-day course for engineers

### **NOVEMBER 7**

Total Quality Management Workshop

### **DECEMBER 6 - 8**

3-day course for plant managers

**AMTC has completed production of a videotape entitled "Generic Architecture for Apparel Manufacturing." Copies are available for \$10 each. If you would like a copy of the videotape, please complete the following form and mail to:**

Ms. Robin Greene  
Apparel Manufacturing Technology  
Center  
209 O'Keefe Building  
Georgia Institute of Technology  
Atlanta, GA 30332  
(404) 894-2215

Make checks payable to: Georgia Institute of Technology

Please send me \_\_\_\_\_ copies of the "Generic Architecture for Apparel Manufacturing" video. I am enclosing a check for \$\_\_\_\_\_.

NAME: \_\_\_\_\_  
ADDRESS: \_\_\_\_\_

PHONE: \_\_\_\_\_



## AMTC Student Views



### William H. Harden

Graduate Student—Georgia Institute of Technology

Major—Industrial and Systems Engineering

Minors—Man-Machine Systems, AI

Education—Certificate in Business and  
Technological Communication  
BIE, Georgia Tech  
MSOR, Georgia Tech

Family—Wife, Bette, is a Research Librarian  
Son, Charles, is in pre-school

Future Plans—To obtain PhD in Industrial Engineering  
and to sail in a transatlantic race.

**Q What attracted you to a position with AMTC?**

**A** Serendipity. I was returning to Tech after a number of years of industrial experience, and ran into Dr. Jane Ammons in the Industrial Engineering graduate office. Subsequent meetings with Dr. Jane Ammons and Dr. Charlotte Jacobs-Blecha indicated that there was a mutual interest in their current research. When I was an undergraduate student, I co-oped with EES before it became GTRI, so I knew AMTC would be staffed by high quality professionals.

**Q What type of overall work responsibilities do you have now?**

**A** My main responsibility is to assist Dr. Charlotte Jacobs-Blecha and Dr. Jane Ammons in evaluating existing Cut Order Planning (COP) software. Future work will involve the development of COP software to be demonstrated at the next annual meeting.

**Q Please describe your participation in current research project with Dr. Charlotte Jacobs-Blecha and Dr. Jane Ammons.**

**A** I have reviewed some of the literature on related topics

since the literature on COP is sparse. Fall quarter, I visited the Russell plant in Alexander City, Alabama, with Dr. Ammons. This quarter, I look forward to comparing the performance of areas for follow-on research. Next quarter, we will be analyzing proposed algorithms in detail before we develop the demonstration software.

**Q Do you feel this type of research participation better prepares you for a career in academic research?**

**A** GTRI and AMTC are widely known for the quality of their research. The project I am involved with will be applying current research findings to real-world problems; this benefits both the apparel manufacturing and the research community. I believe that this is the best type of research.

**Q Doesn't your work with AMTC interfere with your sailing?**

**A** Sailing and apparel manufacturing have several synergistic relationships. Knowledge of sail-making operations has been helpful in the AMTC work and apparel manufacturing research has provided topics for thought during offshore sailing.

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**GTRI**

*Southern Institute of Technology  
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# AMTC



## Evaluating New Technology

Various technological developments in both equipment and methods of production offer the apparel industry opportunities to modernize and gain a competitive edge in the apparel industry. Among them are computer-aided design; computer assistance in virtually all manufacturing areas; new methods for organizing, tracking, and managing production; and opportunities for integrating various aspects of the business. Many of the benefits offered by these opportunities are difficult to quantify. As a result, industry often tends to overlook them. However, when these benefits are ignored, significant current profits and future opportunities may both be lost.

The application of each technology offers a similar set of benefits. However, the characteristics of each technology and differences in applying each technology cause the level of benefits to vary. The list (on the right) of common, but difficult-to-quantify benefits are examples to consider when evaluating equipment purchases. All are important considerations, and many may be critical to making the right choice.

Proper consideration of these benefits demands that information be shared among several facets of the business, particularly production and marketing, and that plans be developed jointly.

Research is currently underway to develop specific approaches to incorporating these benefits into the equipment evaluation process. For more information concerning this research, please contact the AMTC office at (404) 894-3636.

☐ **Experience:** easier upgrading when even newer technologies become available.

☐ **Quality:** fewer rejects, less rework, greater customer satisfaction.

☐ **Integrated Production Functions:** improved line balancing; quicker response to changing product demands; improved management information on quantity, quality, and timeliness.

☐ **Human Factors:** increased safety, lower employee turnover, improved morale, improved productivity, reduced training requirements.

☐ **Precision:** less scrap, increased manufacturing speed and accuracy.

☐ **Plant Layout:** reduced need for future construction, greater flexibility in organizing material flow and equipment placement.

☐ **Material Handling Efficiency:** reduced work-in-process and final goods inventory, reduced throughput times allowing a quicker response to customer needs.

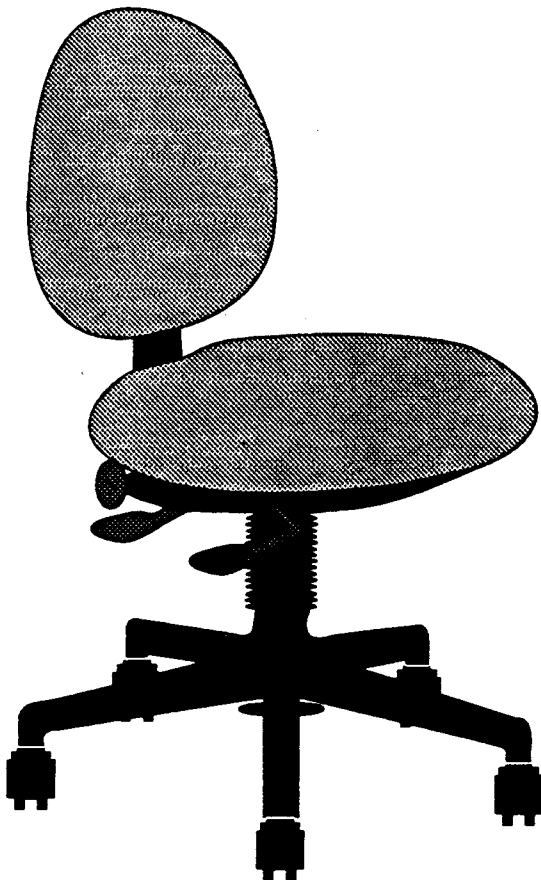
☐ **Adaptability:** to new markets, products, and designs; less manufacturing system obsolescence.

**Dr. William Riall**  
*Economic Development Laboratory*  
*Georgia Institute of Technology*

# AMTC



## Chair Design Criteria for Employee Workstations



A well designed chair will help maximize operator productivity while reducing the incidence of lower-back-related health problems. In general, a workstation chair should meet all of the following criteria:

1. The chair should have five legs for structural stability. It should be on casters if the operator stands and sits or frequently moves about at the workstation. If workers must place or obtain materials to or from their side, the chair should swivel to prevent upper body twisting.
2. The height of the chair seat should be adjustable, usually between 15 and 21 inches for sitting tasks. For alternate sit/stand workstations, the chair height should be compatible with the heights of the work surfaces, such that the relationship between the upper body and the two work heights stays the same. Footrests should also be provided. They should have a nonskid surface, be 12 inches to 16 inches long, and slope 30 degrees or less.
3. The backrest should be between 13 inches and 18 inches wide and easily adjustable between 4 inches and 9 inches above the seat cushion. If the backrest is nonadjustable, it should start no higher than 4 inches above the seat cushion, and extend about 18 inches up.

*continued*

4. The seat cushion should conform to the following criteria:

- ☐ The seat cushion should be firm, but not hard, and preferably of some non-slip fabric type material. This will help reduce the buildup of body moisture.
- ☐ The seat cushion should be slightly hollowed (i.e., concave).
- ☐ The front edge of the seat cushion should curve downward. This facilitates good blood circulation to the feet because it eliminates the pressure point on the underside of the thighs.
- ☐ The seat cushion should be about 18 inches across and 16 inches from front to rear (plus or minus 1 inch).
- ☐ The seat cushion should usually be horizontal. However, adjustable backward tilts of 0 to 8 degrees have proven beneficial in shifting the body's weight against the backrest.

5. For primarily physical work tasks, armrests should be carefully evaluated because they tend to restrict the natural movement of the arms. For primarily nonphysical work tasks, the armrests should be at least 19 inches apart, 9 inches above the seat cushion, and about 3 inches wide (plus or minus 1/2 inch).

6. Ideally, no tools should be required to make adjustments to the chair, so that each operator can easily find the optimal position through trial and error. The user of the chair should be instructed on how to adjust the chair.

No single chair is optimal for all work tasks. The chair's design should be matched to the overall functional design of the workstation and to the tasks being performed at the workstation.

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# AMTC



## New Technology Systems: People Can Make (or Break) Them

### Case 1:

*A large apparel manufacturer had purchased \$250,000 worth of computer-controlled manufacturing equipment to upgrade its operation. But after 15 months, instead of contributing to productivity, the system sat idle in the middle of the plant. Managers were puzzled and disillusioned. Workers were disgruntled. And someone seriously proposed that the firm donate the equipment to a local university because it wasn't working out.*

### Case 2:

*A small apparel manufacturer had purchased \$300,000 worth of computer-controlled manufacturing equipment to increase its competitiveness in a tight market. After 9 months, production output was up by 50%, unit costs were down by 40%, and the firm had new contracts because of its shorter response time. The system also helped reduce operator absenteeism and tardiness.*

THE MANUF.

The difference between the two cases above is not just plant size or capacity. Nor is it the compatibility of the system with the operation — both plants had technical problems that had to be ironed out with the vendor. What is different is the approach that was used to implement the new technology. Georgia Tech researchers studied the first case in-depth and compared results with successes such as the second case. Lessons that other plants can learn are as follows:

- ☐ Be careful to provide sufficient time and talent to implement the system and get it running to the

point that it is accomplishing at least some of the established goals. It will probably take more than you think it should.

- ☐ If the new technology represents a radical shift in production methods, treat it as an R&D project until all the operational bugs have been worked out by your people and with your product.

- ☐ Many computer-controlled systems require some coordination across departmental boundaries. A high-level manager must ensure that this coordination actually occurs. A staff engineer who must beg the plant manager for support and resources will not be able to implement the system effectively without this "champion" at a higher level.

- ☐ Workers unfamiliar with the equipment probably won't be as enthusiastic about the new system as you are. In the early periods of implementation, try to show concern for (1) their problems in learning to use the new equipment, and (2) the constant adjustments they will need to make while management and engineering tinker with the system.

- ☐ Involve workers with various aspects of the technological change so that they feel they have some control over the changes.

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Georgia Institute of Technology  
College of Management

# AMTC



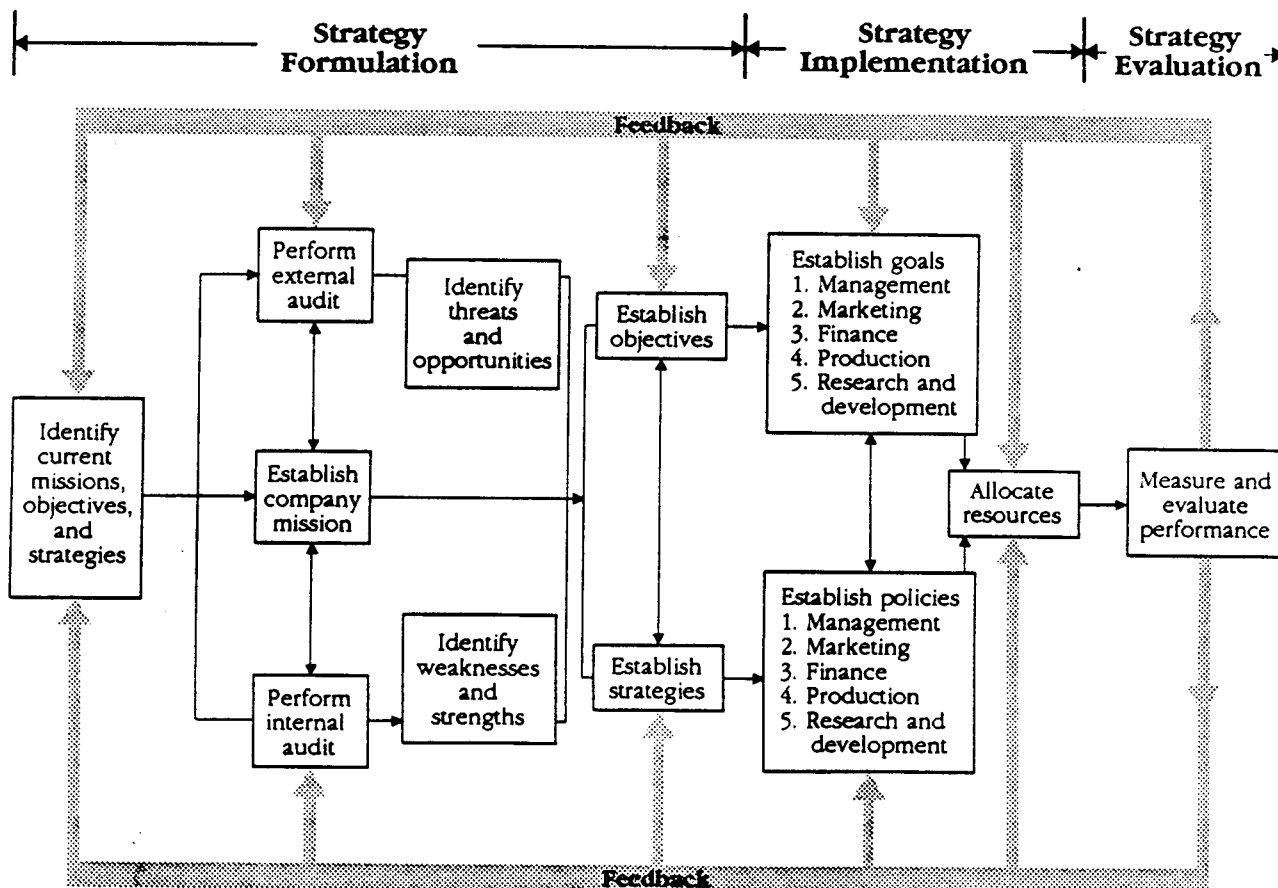
## Strategic Management

Many decisions that managers make are strategic — the effects can be major and have irreversible consequences for the organization. Managers therefore should seek strategies that capitalize on internal strengths, take advantage of external opportunities, temper internal weaknesses, and minimize the impact of external threats.

Strategic management requires research analysis, decision-making, commitment, discipline, and a

willingness to change. The action goals established in the process should concentrate on doing the right things (effectiveness) along with doing things right (efficiency). The organization's success or failure can reflect how fully the strategies were developed.

The strategic management process consists of three stages with feedback loops at each stage: *strategy formulation*, *strategy implementation*, and *strategy evaluation*.



Source: *Fundamentals of Strategic Management*, Fred R. Davis, 1986 Bell & Howell Company

continued

**Strategy formulation** establishes a mission, determines internal strengths/weaknesses and external opportunities/threats, and develops long-term objectives and strategies. The research, analysis, and decision-making required to establish the strategy formulation process can be summarized for evaluation by an analytical matching tool called the Threats-Opportunities-Weaknesses-Strengths (TOWS) Matrix. Matching is a way to align internal and external factors to formulate feasible strategies. The TOWS Matrix helps you develop the strategies necessary to optimize both internal and external conditions. After you define your strategies, you decide what long-term objectives to establish.

**Strategy implementation** is the action stage — setting short-term goals. This stage causes companies the most trouble because it requires personal commitment, discipline, and sacrifice.

In fact, motivating employees to meet the established goals and take personal interest in the success of the organization is a major part of the implementation process.

**Strategy evaluation** ensures that actual results are consistent with planned results. It sometimes requires taking corrective actions. The evaluation of the strategic management process is very important to the well-being of an organization. The purpose is to allow management to identify problems or potential problems before a situation becomes critical.

AMTC staff can provide more information about strategic management. Call (404) 894-3636.

**Elliot Price**  
Georgia Institute of Technology  
Augusta Regional Office

TOWS MATRIX	Strengths - S	Weaknesses - W
	1. 2. <i>List strengths</i> 3. 4.	1. 2. <i>List weaknesses</i> 3. 4.
Opportunities - O	SO Strategies	WO Strategies
1. 2. <i>List opportunities</i> 3. 4.	1. <i>Use strengths to take advantage of opportunities</i> 2. 3. 4.	1. <i>Overcome weaknesses by taking advantage of opportunities</i> 2. 3. 4.
Threats - T	ST Strategies	WT Strategies
1. 2. <i>List threats</i> 3. 4.	1. 2. <i>Use strengths to avoid threats</i> 3. 4.	1. 2. <i>Minimize weaknesses and avoid threats</i> 3. 4.

Source: *Long Range Planning*, Heinz Wehrich, "The Tows Matrix / A Tool for Situational Analysis," 1982 Pergamon

# AMTC



## Workable for Apparel Flexible Manufacturing Systems

**Q What is it?**

**A** Flexible Manufacturing Systems (FMS) is a manufacturing philosophy in which each work station can process a variety of workpieces with relatively short changeover times. FMS is intended to serve the middle ground of batch manufacturing where the workpiece variety is too low for dedicated processes and too high for stand alone machines.

**Q Is a high level of automation required?**

**A** Not necessarily. The level of automation should be based on the availability of the technology required to meet manufacturing requirements in a cost-effective manner. However, computer integration may be required to allow standard equipment to operate as a unit.

**Q What are the benefits?**

**A** The notion is to apply a set of more general purpose tools to produce a greater range of products. Flexibility can be viewed as a firm's ability to vary what it produces — to adjust operations at any moment to changes in the mix of products the market demands, or to increase productivity through improvements in production processes and product innovation. Other benefits include reduced total throughput time, reduced

level of total inventory (raw materials, work-in-process, and finished goods), and broader style/fabric capabilities.

**Q What are the requirements for FMS?**

**A** Lay and Webb (1988) have described some of the requirements for the apparel industry as follows:

- ☐ Smaller lot sizes
- ☐ Quality assurance at the source
- ☐ Broader operator skill bases, featuring cross-training and the ability to accommodate job changes quickly
- ☐ Greater employee involvement in the total manufacturing process
- ☐ New forms of employee motivation and compensation, including more emphasis on group effort and total performance rather than individual productivity
- ☐ Development of problem prevention methods
- ☐ More sophisticated information systems and computer controls of workflow.

**Q What changes in the apparel industry are needed to take advantage of FMS?**

**A** Lay and Webb (1988) suggest the following approaches to making the apparel industry more flexible. First, there must occur an integration of the planning and support systems that surround the manufacturing process with the

*continued*



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rest of the manufacturing enterprise:

- ☐ Product development and costing, materials procurement, scheduling, marking, cutting, finishing, and distribution systems must cease to operate independently of manufacturing.
- ☐ An information system must coordinate and integrate the system from product design to customer delivery. This includes electronic communications with both suppliers and customers.
- ☐ The manufacturing enterprise should take advantage of computer applications which make it possible to achieve shorter, more efficient planning and operating systems.

Second, innovation of equipment and methodologies is needed. New technologies such as the unit production system, CAD systems for automated marking and cutting, automated sewing equipment, and automated material handling should be given serious attention and analysis. New work methods and system layouts such as modular manufacturing, operator cross-training, and cooperative group effort should also be given consideration.

## Q What is the best approach to the design of FMS?

A Young and Greene (1986) offer the following action plan as a systematic approach to FMS design that draws on the total resources of the company:

1. Define manufacturing objectives.
2. Establish an FMS project team.
3. Understand the technology involved including PLC's (programmable logic controllers), MRP (material requirements planning), GT (group technology), CIM (computer integrated manufacturing), and similar terms related to the FMS concept.
4. Conduct a preliminary evaluation.
5. Prepare requests-for-proposals and evaluate vendor proposals.

Research is underway to develop specific approaches to incorporating FMS into the apparel manufacturing process. For more information concerning this research, please contact the AMTC office at (404) 894-3636.

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Economic Development Laboratory  
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# AMTC



## Save Money By Repairing Air Leaks

**L**eaks in compressed air lines cost money. Managers at one apparel plant where knit shirts are cut, sewn, and finished found out just how significant these leaks can be. They saved almost \$600 a year by repairing five leaks at a cost of \$50 each. That's a simple payback of less than a year.

Georgia Tech's Energy Resources Group has prepared a table to enable quick calculation of the

power costs associated with compressed air leaks. The apparel plant mentioned above found five leaks, three at 1/8 inch in diameter and two at 1/16 inch. Air compressor discharge was 70 psig (pounds per square inch gage). At a power cost of 5¢ per kilowatt-hour and 2,000 hours of annual operation, the plant was wasting 5,242,000 cubic feet of free air per year at an energy cost of \$587. A sample calculation using the table values are shown below:

$$\text{Power cost} = 3 \text{ leaks} \times \frac{167.80}{\text{leak}} \times \frac{(2,000/2,000)\text{hr}}{\text{yr}} + 2 \text{ leaks} \times \frac{41.80}{\text{leak}} \times \frac{(2,000/2,000)\text{hr}}{\text{yr}} = \$587.00$$

By a leak of air  
at 70 psig

By a leak of air  
at 100 psig

Hole Diameter [inches]	Free Air Wasted <sup>1</sup> [cubic feet/year]	Cost of Power Wasted <sup>2</sup> [dollars/year]		
		at 4¢/kWh	at 5¢/kWh	at 6¢/kWh
3/8	13,493,000	\$ 1,210.00	\$ 1,506.80	\$ 1,808.00
1/4	5,981,000	534.00	670.00	804.00
1/8	1,498,000	134.00	167.80	201.00
1/16	374,000	33.50	41.80	50.00
1/32	94,000	8.40	10.50	12.60
3/8	18,037,000	\$ 1,995.00	\$ 2,494.00	\$ 3,000.00
1/4	8,105,000	885.80	1,107.00	1,331.50
1/8	2,009,000	221.90	276.70	332.90
1/16	507,000	55.25	69.04	83.00
1/32	126,000	13.80	17.00	20.70

<sup>1</sup> Based on nozzle coefficient of 0.65.

<sup>2</sup> Based on 18 brake horsepower per 100 cubic feet of free air per minute for 70 psig air and 22 brake horsepower per 100 cubic feet of free air per minute for 100 psig air.

Note: Table shows values for 2,000 hours of operation. To obtain values for different hours of operation, multiply table values by the ratio of actual hours to 2,000 hours.

Hint: Use a soap & water solution to find the exact location of a leak

Adapted from Industrial Energy Extension Service Energy Tip No. 13

## **APPENDIX C**

### **Descriptions of AMTC Research Projects**

**TECHNICAL REPORT, FINAL**  
**APPAREL MANUFACTURING**  
**TECHNOLOGY CENTER**

**CONTRACT NUMBER: DLA900-87-D-0018-0008**

**PERFORMANCE PERIOD: 890405 - 891024**

Submitted By:

John Adams, P.E.

Economic Development Laboratory  
Georgia Institute of Technology  
Georgia Tech Research Institute

November 1, 1989

Sponsored By:

**THE UNITED STATES DEPARTMENT OF DEFENSE**  
**DEFENSE LOGISTICS AGENCY**

The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Defense Logistics Agency position, policy, or documentation.

**PROGRAM OBJECTIVE:**

The objective of this short term task is to demonstrate state-of-the-art apparel manufacturing design technology to the Chief of Staff of the Army.

**PROGRAM SCOPE OF WORK:**

Georgia Tech is to set up two demonstrations of the latest apparel manufacturing design technology. The first demonstration will be a rehearsal for the second. The audience for the first demonstration will be DLA personnel and the demonstration will be held at Cameron Station, Alexandria, Virginia on a date to be determined. The second demonstration will be provided to the Chief of Staff of the Army and will be held at the Pentagon, Washington, DC on the date to be determined. The length of the second demonstration will be 30 minutes.

Final Report

for

**MEASURING THE EFFECTIVENESS  
OF THE  
APPAREL ADVANCED MANUFACTURING  
DEMONSTRATION PROGRAM**

to

Defense Personnel Support Center  
Philadelphia, Pennsylvania

Covering the contract period  
August 20, 1987 - August 20, 1990  
for  
Contract DLA900-87-D-0018

Submitted by  
Georgia Tech Research Corporation  
Georgia Institute of Technology  
Atlanta, Georgia

*December 30, 1990*

## I. INTRODUCTION

This report is based on research and analysis carried out by AMTC during 1989 and 1990. The project is called "Measuring the Effectiveness of AAMTD." The goal is to evaluate the effectiveness of activities undertaken by AMTC and the benefits to the U.S. apparel industry.

In June 1989, DLA issued a Request for Proposal (RFP) to the three centers to begin specific measurement processes to determine project effectiveness. It is very appropriate for a program sponsor to assume a "results oriented" approach in measuring program performance. This inspires the contractor to undertake activities which are most likely to yield the results desired by the sponsor. In such mammoth programs as AMTC, it is easy to get caught up in the activities and events themselves, and fail to concentrate on the outcome or benefits.

**DISCRETE-EVENT SIMULATION  
APPLIED TO APPAREL  
MANUFACTURING**

**by**

**Jude T. Sommerfeld**

**Wayne C. Tincher**

**Pamela S. Rosser**

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**FINAL REPORT**

**for**

**Defense Logistics Agency  
U. S. Department of Defense**

**June, 1990**



## Introduction

Simulation has been a commonly accepted engineering tool and manufacturing aid in many industries for more than thirty years now. Specifically, discrete-event simulation [1] is commonly employed by industries engaged in discrete parts or items manufacturing, e.g., machine tools, vehicles, appliances, etc. Very few applications of simulation and, particularly, of discrete-event simulation in the textile and clothing industries have been reported in the literature, however.

The manufacture of apparel, of all sorts, can be described as a sequence of parallel and consecutive discrete events, each with its own characteristic inputs, outputs and time requirements. Thus, such a manufacturing system readily lends itself to discrete-event simulation. Traditionally, the clothing industry has not been particularly noted for the development of sophisticated new technology or new manufacturing systems [2]. However, in the recent past and with the pressures of quick-response manufacturing, this industry has shown renewed interest in applications of computer-based tools to manufacturing systems. Simulation, which has been a widely used tool in other industries, has received considerable attention for its possible applications in apparel manufacturing.

To date, however, little application of discrete-event simulation in the overall textile industry (knitting/weaving, finishing, apparel manufacture) has been reported in the open literature. In one of the few known studies in this area, the General Purpose Simulation System (GPSS) was used to model and perform a discrete-event simulation of a large textile finishing mill, producing a variety of woven and knit fabrics for sheeting and men's and women's apparel [3]. This model was validated with actual mill operating data. Simulations were made to determine the effects of market demands, maintenance practices, quality control policies, and total production on equipment and manpower utilization, work-in-process (WIP) inventory, and total processing time, such as measured in any just-in-time (JIT) program. There also recently appeared a simplified application of GPSS/H to the modelling of T-shirt manufacturing (4).

**July 1989 - June 1990 .**

## **2. Technical Analysis**

### **2.1 Introduction**

The technical part of this study has concentrated on three key areas. Initially, the work focused on commercial vendors who market software (and hardware) systems for processing the marker making problem. Vendor participation was solicited, a survey was constructed and administered to these vendors to determine the composition of the state-of-the-art technology, and users of these commercial systems were visited to get a more practical view of the software. This part of the study is discussed in section 2.2. Another large component of this study is directed at an analysis of the underlying optimization problem, known as the *cutting stock problem*, with respect to marker making. An extensive literature review was performed, from which specific conclusions have been made. This review and analysis is presented in section 2.3. The final phase of the study looked into new techniques for marker making and suggestions for future research. Two such possibilities, expert systems and neural networks, are discussed in section 2.4.

**SHORT TERM TASK  
FINAL REPORT**

**CUT ORDER PLANNING**

**Co-Principal Investigator: Dr. Jane C. Ammons  
Co-Principal Investigator: Dr. Charlotte Jacobs-Blecha  
Research Investigator: Terri Smith  
Research Assistant: Avril Baker  
Research Assistant: Bill Warden**

**Georgia Institute of Technology  
Apparel Manufacturing Technology Center  
Computer Science and Information Technology Laboratory  
School of Industrial and Systems Engineering**

**October, 1989 - May, 1991**

**Research Sponsored by:  
U. S. DEFENSE LOGISTICS AGENCY  
Contract: DLA900-87-D-0018  
Georgia Tech Project No.: A-8496**

## **1.0 Introduction**

### **1.1 Overview**

To reestablish a competitive position in the international marketplace, the apparel industry is focusing on upgrading its responsiveness to customer needs. Smaller orders are placed in a more dynamic fashion, forcing the efficient production of smaller lots.

Responsive and economical production of apparel products depends upon the interaction of many components, one critical component being an efficient workflow control system. The cut order planning (COP) process is a dynamic one in that the procedure must respond to the ever changing status of many critical factors such as sales, inventory levels, raw materials, and labor and equipment availability. The variety of sizes, styles, fabrics, and colors induces significant complexity in this problem. Adding to the complexity, and thus potentially increasing total production costs, are such considerations as setup, or changeover costs, the question of appropriate lot sizes, the necessity to meet customer demand, and the importance of making competitive delivery promises.

This project has undertaken the study of improving systems for cut order planning to improve the productivity and competitiveness of apparel manufacturers.

### **1.2 Scope of the Project**

The objective of this project has been to investigate appropriate methodologies for cut order planning. First, existing software packages have been examined and their performances comparatively analyzed, utilizing testbed data. Second, a theoretical analysis of the cut order planning process has been performed and appropriate algorithms developed. The approach derived from the theoretical analysis has been implemented in a prototype software package developed for the purposes of experimentation and evaluation of the algorithm.

Two products have resulted from this research. First is an understanding of the relative performance of currently available software for cut order planning and the relative priorities of the cost drivers for the planning decisions. Second is a set of new algorithms implemented in a prototype software package which have been structured for future integration into commercially available software systems.

SHORT TERM TASK  
FINAL REPORT

**FLEXIBLE WORK GROUP METHODS**  
**IN APPAREL MANUFACTURING**

Charlotte Jacobs-Blecha, Project Director  
Computer Science and Information Technology Laboratory

John J. Bartholdi  
Donald D. Eisenstein  
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School of Industrial and Systems Engineering

Richard Carey  
Jon Lindbergh  
Steve Nichols  
Electronic Optics Laboratory

Georgia Institute of Technology

September, 1989 - April, 1993

Research Sponsored by:  
U. S. DEFENSE LOGISTICS AGENCY  
Contract No.: DLA900-87-D-0018-0010  
Georgia Tech Project No.: A-8496

## **1.0 Introduction**

### **1.1 Overview and Problem Definition**

In the apparel industry, Flexible Work Groups (FWGs)\* are teams of workers cross-trained in several operations which carry out entire assembly processes and are compensated as a group rather than individually. The emphasis is on group effort and employee involvement, quality at the source, and short throughput time. This concept is being used in a number of production areas similar to apparel, such as shoe and curtain manufacture. Exploration of this manufacturing method is ongoing in the apparel industry, and many makers have expressed a strong interest in the concept.

In addition to the impact on productivity, there is likely to be an equally important impact on quality. People working together as a team are likely to be more consistent in the accuracy with which they perform their jobs. In this setting, there is the opportunity for real-time feedback as to fabric and sewing defects before the garment is completely assembled. This translates into raw material savings as well as a reduction in required production repetitions. In addition, the team members are apt to establish more pride in their work and motivation to assemble defect-free garments in their group. Producing high quality, defect-free garments is necessary to gain consumer confidence and to increase the competitiveness of U.S. apparel makers with overseas manufacturers.

A third benefit of the FWG philosophy may be a significant reduction in work-in-process (WIP) inventory, and the corresponding reduction in required plant floor space and carrying costs. The savings associated with reduced inventory are reflected along the entire inventory pipeline, including the supplier level. Furthermore, the physical reduction in WIP can greatly reduce flow congestion and thereby enhance material control.

The FWG concept brings a new set of challenges. For example, the question of how the manufacturing processes will actually be carried out becomes a much more complex one. This involves not only the layout of the equipment, but also a careful evaluation of which operations will be incorporated into the work module, which operators will work in the group, and which operator will perform which operation. In addition, the overall manufacturing process is likely

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\* These groups are also called Modular Manufacturing Groups. We will use both terms in this report.



to require a much more complex control strategy and tracking system for order progress to be updated.

The FWG concept brings social as well as technological challenges. First, the implementation of a FWG requires a cooperative and conscientious attitude from those persons working in the FWG. This may be brought about by the use of proper training and various incentive programs. Operator absenteeism becomes a problem when team operation depends upon everyone being present and contributing. In addition, the team concept requires a great deal more self-management, offering an even greater challenge to the workers involved. This is also likely to mean that plant managers must become more flexible and must set more realistic goals for meeting market conditions.

We make some basic assumptions concerning the enterprise in which the FWG will operate and what issues we will address. We assume the task (or tasks) to be accomplished by the group has been predetermined. We do not address the social issues. We focus only on the "how to" of improving the performance of the flexible work group.

# **ANALYSIS OF DEFECTS IN TROUSER MANUFACTURING: DEVELOPMENT OF A KNOWLEDGE-BASED FRAMEWORK**

## **Volume I: Final Technical Report**

Research sponsored by

Defense Logistics Agency  
DLA-PRM  
Cameron Station  
Alexandria, Virginia

DLA Contract #: DLA-900-87-D-0018-0003

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Georgia Tech Project #: E-27-637

November 1988 - November 1991

SJ-TR-DEFE-9202

# **CHAPTER I**

## **INTRODUCTION**

The U.S. apparel industry is currently undergoing rapid changes to operate successfully in a highly competitive global market. One obvious way of being successful is to significantly improve the quality of domestic products. In addition to fetching a premium price, improved product quality accounts for customer satisfaction and consistent consumer demand.

The increasing emphasis in the apparel industry on "on-line" quality control highlights another important application of this research effort. Every assembly operation in trouser/apparel manufacturing adds value to the product. The detection of a defect and initiation of remedial measures right at the stage at which the defect occurs will mean not only fewer defective garments but also reduced wastage of production resources. Thus, there is a need to simplify on-line quality control procedures, to set up a formalized approach for tracking defects occurrence and to analyze their causes with the primary goal of instituting remedial measures.

Many apparel plants, as they function today in the United States, do not maintain an accurate record of quality performance on a day-to-day basis. A continuous tracking and recording of defects is essential to positively influence quality levels over an extended period of time. Quality records must be maintained not only for the plant as a whole but also for the various production equipment and individual operators.

Considering all the above factors, it is clear that there is a need not only to investigate the problem of defects in garment manufacturing but also to build an intelligent system that can record, identify and diagnose defects occurring in garment manufacturing.

# COMPASS

Software for Assessing Equipment Investments in the Apparel Industry

Prepared by  
William Riall, Ph.D.  
Robert Lann

With support from  
U.S. Defense Logistics Agency

Under the  
Apparel Manufacturing Technology Center

Georgia Institute of Technology  
Georgia Tech Research Institute  
Economic Development Laboratory

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# 1: Introduction

COMPASS is a tool designed to help the apparel industry decision-maker evaluate equipment investments. It runs on any IBM-compatible computer with a high-density 5 $\frac{1}{4}$ " drive or a 3 $\frac{1}{2}$ " drive and at least 640k of RAM installed. It works best when used with a color monitor, and the faster the machine, the better. It is advisable to use COMPASS on a machine with a hard drive.

COMPASS is a software tool similar to other cost/benefit analysis methods in that it uses a discounted cash flow to measure benefits. COMPASS differs from other methods in two important ways, however. First, it has a larger set of cost items, some not usually quantified by other methods, to ensure that all of the costs and benefits are considered. Second, it provides a way to score alternatives using both strategic and cost information.

The structure of COMPASS is similar to many other software packages, so it will be easy to learn and familiar to you in some ways. Various menu items are presented which, when chosen, either offer additional menu items or request information from you. Online help is available to define terms and/or offer explanations of how to proceed for each item. Help can be displayed with <F1> at any time. The help screens are context sensitive, in that they provide specific information regarding the menu item you have highlighted. Help messages cannot always fit on one screen. Use the up and down arrows or <Pg Up> and <Pg Dn> to scroll through the text.

At the top of each help screen is the title corresponding to the item that was highlighted when you pressed <F1>. Often, a single message pertains to several menu items.

COMPASS uses a menu system structured like a tree with many branches (as illustrated in the tables throughout this manual). You can choose items either by pressing <ENTER> or by clicking the left mouse button when your selection is highlighted. Dragging the mouse also highlights a choice.

In many cases, the result of making a choice will be another menu, from which further choices can be made. When using a mouse, you may be tempted to try to move from the end of one menu to another in one click. Sorry, but you will have to move back up the menu branch you're on (with successive clicks of the right mouse button, or <ESC>) before you can move down another.

Messages at the bottom of the screen offer directions for either moving around the screen or proceeding to the next step in the analysis. These messages include how to use special keys for the screen you are viewing. While not all special keys apply to each screen, the special keys are consistent from screen to screen. For example, <F4> will always clear data from a screen, but only a screen that has spaces for data to be entered.

APPAREL ADVANCED MANUFACTURING TECHNOLOGY  
DEMONSTRATION

SHORT TERM TASK  
FINAL TECHNICAL REPORT  
( IMPLEMENTATION: INDUSTRIAL APPLICATION )

In-Process Quality Control In Apparel Production:  
Sewing Defects

to

DEFENSE LOGISTICS AGENCY

Contract: DLA 9000-87-D-0018 -0006

by

Georgia Institute of Technology  
School of Textile & Fiber Engineering

November 1993

# **In-Process Quality Control In Apparel Production: Sewing Defects**

## **FINAL TECHNICAL REPORT ( IMPLEMENTATION: INDUSTRIAL APPLICATION )**

### **1.0 Project Overview**

#### **1.1 Introduction**

Previously, work was undertaken in learning about techniques that would contribute to the real time detection of sewing defects in an automated or manual sewing process. This report discusses efforts on several fronts to design and produce a detector for sewing defects, and the results of carrying this technology to industrial sites for evaluation. A device for thread motion analysis has proved very successful in plant trials and has generated strong interest in finding means for commercialization of the device. First, a few comments are in order on the reason for undertaking this effort and on the prior work leading to this research.

Rapid detection of a sewing defect is important to optimization of the relationship between quality and productivity. Defects found after sewing adversely affect costs. There is distinct advantage to identifying a defect before other operations hinder seam removal and resewing. Also, the automated assembly operations, which are being developed and used in part now and that are seen for the future, require on-line quality control if the automation is to succeed. This observation is based upon the current system in which the operator serves as the first line of quality control implementation.

Automated sewing stations have no operator to serve in the first line quality control position, leaving quality checks to later stages, after value adding operations are performed on substandard goods. Even multitask workstations need quality control automation, because the operator is handling multiple tasks and is unable to view them all at once. Implementation of statistical process control is dependent on automated quality determination in the automated sewing environment. Most technical experts from industry agree that the efforts on automation and labor reduction in machinery for the apparel industry have not been accompanied by efforts in automated quality control devices. Work in this area has been attempted in both Europe and in this country. The problem is that the sewing process has proven very difficult to monitor and control, particularly using commonly accepted devices from other industries. The work done herein shows that inconsistency within the process when the process is under control, i.e. within acceptable limits and producing acceptable sewn seams, is beyond the tolerance for which most quality control sensing systems have been designed. Data appears to be noise, and the problem is handling the imbedded information within that noise.1

The previous research and development task had the goal of providing an automatic, in-process quality control system for the detection of sewing defects as they occur. Phase I. of research efforts was entitled "Defects Assessment" and had as its objective the identification of common types of sewing defects. Phase II., titled "Defect Cause and Detection", had the objective of identifying defect cause and potential real-time means of detection of faults. Phase III., titled "Technology Demonstration", had as its objective the laboratory implementation of the detection means for defects identified in Phases I and II. This has been reported in a final report covering the work done under Phases I, II, and III, written in October 1991 under contract # DLA 9000-87-D-0018, CLIN 0007.



**FINAL REPORT**

**DETECTION AND REMOVAL OF DEFECTS IN  
APPAREL PRODUCTION**

By  
Wayne Tincher, Wayne Daley and Wiley Holcombe

Prepared for  
Defense Logistics Agency

Under  
Contract DLA 900-87-D-0018-0007

March, 1993

# DETECTION AND REMOVAL OF FABRIC DEFECTS IN APPAREL PRODUCTION

Wayne C. Tincher, Wayne Daley and Wiley Holcombe  
Georgia Institute of Technology  
Atlanta, Georgia 30332

## I. INTRODUCTION

Fabric defects are a constant and continuing problem in the manufacture of apparel. Despite major improvements in yarn manufacturing equipment and knitting and weaving machines, it is not possible at the present time to manufacture defect free fabric. In an era when "zero defects" is the goal of most textile mills, it must be admitted that this still remains a goal and not an accomplished objective.

Defects in fabric create significant problems for the apparel manufacturer and a variety of systems have been developed to cope with the defect problem. Some firms conduct 100% inspection of in-coming fabric, mark or label detected defects and attempt to remove all fabric defects in spreading. Other firms depend on inspection during spreading by the spreader operator and the removal of the detected defects prior to cutting. A few firms depend on sewing operators to detect flaws in cut parts and to replace the parts before manufacturing proceeds. Still others make no attempt to find fabric defects during manufacturing, but rely on final garment inspection to detect and remove defect containing garments. In a few cases, cut parts are examined individually before bundling and defective parts are replaced prior to initiation of the sewing operations [1].

All these methods of coping with fabric defects are costly and disruptive in the apparel manufacturing process and most are not successful in eliminating fabric defects in finished garments. Therefore, fabric defects are a major point of conflict at the textile and apparel industries interface. Study of this problem has been the subject of continuing investigation in the military procurement system but no satisfactory solution is apparent [2-4].

The problem of detecting and removing fabric defects increases in severity as more apparel operations are automated. Automated spreading machines requiring less worker attention reduce the probability of finding defects and, in some cases, of finding markers that have been placed on the fabric denoting the location of defects. With fewer workers handling parts in sewing operations, the probability that a defect will be detected decreases.

Most of the effort at the present time in automatic detection of defects in fabric is directed toward inspection of fabric rolls. A number of companies either have, or will market in the near future, systems for automatic roll inspection [5]. The unfortunate disadvantage of these systems is that if defects are detected they can only be marked (or cut out and replaced by a seam which is another defect). The defect must still be removed with the fabric loss and time loss involved in such defect removal. The approach taken in this work is to develop systems to automatically inspect cut parts and only remove those parts from the production process which are defective. This approach should significantly reduce the fabric loss due to defects and

should decrease the number of fabric defects that go through the entire assembly process and result in garment seconds.

## **DESIGN AND DEVELOPMENT OF AN AUTOMATED BELLOWS POCKET AND FLAP SETTER**

### **Introduction**

Attaching the two bellows pockets and associated cover flaps, located on the out seams of the Battle Dress Uniform (BDU) trouser, requires complex and time consuming work from a highly skilled sewing operator. The same pocket design is incorporated on the BDU coat as well as a number of other DoD garments. Typical assembly time of 2 minutes per trouser (31 minute total assembly standard allowed minutes for trouser assembly) represents one of the most complex and time consuming assembly operations of the entire garment. This project endeavors to cost effectively automate the process using existing technology with suitable modifications to minimize project risks and to maximize ease in implementation. Current ideas consider the employment of a traditional automated patch pocket setter with a robotic clamp. This may reduce attachment time by more than one half. Unfortunately, this cargo pocket design is not prevalent on civilian garments. Thus, sewing equipment manufacturers have little incentive to make the necessary developments because of the lack of mastery in government specifications/unique contractor requirements, and the small market potential. The project team will endeavor to accomplish the project mission while offering developments that will accommodate a large number of garments. Successful implementation of this project will reduce the direct-labor component of BDU manufacturing by more than 3 percent. Initial work will focus on the coat lower cargo pockets because of the smaller dimensions, thus increasing the likelihood of success. Later in the project, the trouser cargo pocket attachment will be pursued. It offers greater technical challenge due to its size and the attachment over a felled seam.

## **GENERIC ARCHITECTURE FOR APPAREL MANUFACTURING: MAINTENANCE AND ENHANCEMENT OF AMA**

The Apparel Manufacturing Architecture (AMA) developed at Georgia Tech during the earlier phases of this research is a blueprint for implementing computer-integrated manufacturing systems in the apparel industry. AMA consists of the function, information and dynamics models. The USAF's IDEF Methodology was used in the development of AMA. With AMA, the *essential* foundation has been laid for making further progress on evaluating and implementing advanced concepts and technologies such as Quick Response, Just-in-Time manufacturing, Electronic Data Interchange and Product Data Exchange Standards in the apparel industry.

Just as continued maintenance, updating and support are essential for any acquired technology (software/hardware/equipment) to have a long and meaningful impact, these three elements -- maintenance, updating and support -- are critical for the successful adoption and proliferation of AMA. The purpose of this phase of the research is to maintain, update and support AMA-related activities. The time-task schedule (see the attached program schedule) enumerates the various activities to be carried out during the course of this research effort.

### **Introduction**

This phase of the research work began in March 1992. This report reviews the progress made during the month of August, 1994. It also outlines the work to be carried out in the coming month. The report provides a means of comparing the actual progress achieved with the original time-task schedule identified in the initial project proposal.

# **KNOWLEDGE BASED FRAMEWORK FOR TROUSER PROCUREMENT: FIELD IMPLEMENTATION AND ENHANCEMENT OF BEST**

The Department of Defense is the single largest consumer of apparel items in the free world procuring approximately \$1 billion worth of apparel every year. The old practice of using sealed bid procedures and awarding contracts to the lowest bidder is giving way to Best Value Procurement. Such an informed and knowledge-based procurement approach would not only help the government but would also have an overall beneficial effect on the apparel industry.

The Bid Evaluation Software Tool (BEST) developed at Georgia Tech during earlier phases of this research is a knowledge-based system (KBS) that can be used to evaluate the capability of an apparel manufacturer to perform on a contract. BEST has been developed in cooperation with major apparel manufacturers and with information furnished by DPSC, Philadelphia. As with any major KBS development effort, BEST has been initially targeted to a significant, yet manageable, domain, viz., trousers.

BEST is implemented in Nexpert Object, an expert system shell from Neuron Data, and runs under both MS-DOS and Unix operating systems. To obtain the necessary information for evaluating a contractor, a set of forms known as BESTForms has been created. BESTForms is available both in hard-copy and electronic versions (Quattro spreadsheet template or ASCII file). BESTProcess, the problem-solving engine in BEST, utilizes the data in BESTForms and comes up with a rank (on a 0-4 scale) for the bidder.

The primary objectives behind this phase of the research are to implement BEST in the field, enhance its scope to include other garments and to interface it with the Contractor Profile System being developed at DLA. The time-task schedule (see the Program Schedule attached) enumerates the various activities to be carried out during the course of this research effort.

## **Introduction**

This phase of the research work began in April 1992. This report reviews the progress made during the month of August, 1994. It also outlines the work to be carried out in the coming month. The report provides a means of comparing the actual progress achieved with the original time-task schedule identified in the initial project proposal.

## **PROBLEM SOLVING FOR APPAREL MANUFACTURERS: IN-PLANT ASSISTANCE**

The **Problem Solving for Apparel Manufacturers: In-Plant Assistance** project continues to assist government contractors in solving problems and improving productivity by applying advanced manufacturing technologies, productivity engineering, and innovative management practices. AMTC is supporting DLA's goal to strengthen the domestic apparel industry by helping individual companies improve their manufacturing capabilities and profitability.

## **APPENDIX D**

### **AMTC Research Presentations and Publications**



Invited Presentations and Articles by AMTC Staff

Major invited presentations, some of which included formal papers are listed below.

- April 1988: Dr. Sundaresan Jayaraman  
Swedish Institute for Textile Research  
"Computer Integrated Manufacturing Research in  
Textiles/Apparel"
- April 1988: Dr. Sundaresan Jayaraman  
Chalmers University of Technology faculty meeting,  
Sweden  
"Research on Textile Structures and CIM in Textiles"
- Sept. 1988: Dr. Sundaresan Jayaraman  
Bobbin Show, CIM Research Committee Conference  
"An Architecture for Apparel Manufacturing:  
Methodology Selection Criteria"
- February 1989: Dr. Wayne Tincher  
Atlanta Textile Club Meeting  
"Apparel Research at AMTC"
- April 1989: Dr. Sundaresan Jayaraman  
International Conference on Textile Education, Clemson  
"Designing a Textile Curriculum for the 90's"
- May 1989: Gerry Doubleday and Frank Mewborn  
1-day conference at Georgia Tech  
"Improving Profits by Eliminating Guesswork"
- June 1989: Gerry Doubleday  
Total Productivity Involvement Conference, Nashville, TN  
"Improving Profits by Maximizing Productivity"
- August 1989: Dr. Bill Riall  
AMTC UPS Applications Workshop  
"Cost Justification of UPS and Other Advanced  
Equipment"

- August 1989: Dr. Sundaresan Jayaraman  
International Joint Conference on Artificial Intelligence  
"On a Manufacturing Enterprise Architecture"
- Sept. 1989: Dr. Sundaresan Jayaraman  
Panel member  
International Joint Conference on Artificial Intelligence  
"On a Manufacturing Enterprise Architecture"
- Sept. 1989: Dr. Sundaresan Jayaraman  
Dr. P. Tung  
American Chemical Society Annual Conference, Miami  
"On Three Dimensional Multilayer Woven Preforms for Composites"
- October 1989: Dr. Mike Kelly  
Human Factors Society National Conference, Denver  
"Human Factors in Apparel Manufacturing"
- October 1989: Dr. Sundaresan Jayaraman  
Session Chairperson  
NIST Workshop on Apparel Product Data Exchange Standards  
"An Engineering Design Approach to APDES"
- October 1989: Dr. Charlotte Jacobs-Blecha  
Dr. Jane Ammons  
Joint National Conference of the Operations Research Society of America and the Institute of Management Science  
"Cut Order Planning for Flexible Trouser Manufacturing"
- November 1989: Dr. Mat Sikorski  
Fiber Society Conference, Raleigh  
"In-Process Quality Control in Apparel Manufacturing"
- February 1990: Dr. Bill Riall  
2nd International Conference on Manufacturing Technology  
"Economic Justification of Technology Acquisition: New Direction and Evidence from the Apparel Industry"

April 1990: Dan Ortiz  
Private Rehabilitation Suppliers Annual Conference  
"Research on Human Factors in Apparel Manufacturing"

April 1990: Dr. Wayne Tincher  
Georgia Tech CIM Center Industry Board Meeting  
"Apparel Manufacturing Research at Georgia Tech"

April 1990: John Adams  
Georgia Tech Research Center Conference  
"Multi-Unit/Multi-Campus Project Administration"

April 1990: Dr. Mike Kelly  
Biennial Symposium on Psychology in DoD  
"Human Factors in the Manufacture of Military Uniforms"

April 1990: Dr. Mike Kelly  
Human Factors Society Conference, Atlanta Chapter  
"Human Factors in the Manufacture of Military Uniforms"

May 1990: Dan Ortiz  
Ted Courtney  
AMTC Ergonomic Applications Workshop  
"Results of AMTC's Human Factors in Apparel Manufacturing"

May 1990: Dan Ortiz  
International Apparel and Clothing Design Conference  
"Human Factors in Apparel Manufacturing"

May 1990: Dr. Wayne Tincher  
International Apparel and Clothing Design Conference  
"Apparel Research at AMTC"

May 1990: Dr. Sundaresan Jayaraman  
The Resurgence of Textile Excellence: A Roadmap for Success in the 90's  
"Material Handling: The Key to Global Competitiveness"

May 1990: Dr. Sundaresan Jayaraman  
First International Symposium on World Class Textile Manufacturing  
"Material Handling: The Key to World Class Manufacturing"

- June 1990: Dr. Wayne Tincher  
Georgia Tech Minorities Undergrad Research Program  
Meeting  
"Apparel Manufacturing Research at Georgia Tech"
- June 1990: Dr. Sundaresan Jayaraman  
Annual Conference, American Society for Engineering  
Education  
"Designing the Manufacturing Engineer of the Future"
- June 1990: Dr. Sundaresan Jayaraman  
Annual Conference, American Society for Engineering  
Education  
"Programming and Software Tools: Need for a  
Synergistic Approach"
- July 1990: Dr. Sundaresan Jayaraman  
International Clothing Conference  
"KES Properties of Difficult-to-sew Fabrics"
- July 1990: Dr. Sundaresan Jayaraman  
International Frontiers in Education 1990 Conference  
"The Challenge of Educating the Engineering Class of  
2000"
- August 1990: Dr. Mike Kelly  
International Conference on Human Aspects of Advanced  
Manufacturing and Hybrid Automation  
"Human Factors in Advanced Apparel Manufacturing"
- October 1990: Dr. Mike Kelly  
National Society for Performance and Instruction, Atlanta  
"Mistakes and Pains"
- October 1990: Dr. Bill Riall  
Technology and Humanities Conference  
"Technology Choice in a Free-Market System"

In 1988, WXIA-TV, in Atlanta, broadcast a special news report entitled "Future Work" which featured AMTC and its programs to assist and educate industry's future employees.

In 1989, CNN broadcast a special report on AMTC and its activities.

JOHN C. ADAMS

BIOGRAPHICAL SKETCH

Major Reports and Publications

1. Adams, J.C., "Industrial Modernization in Small Apparel Manufacturing Enterprises in the 1990's," 4th Annual Academic Research Conference, Raleigh, NC, February 1993.
2. Adams, J.C., "Industrial Automation and Modernization in Small Manufacturing Enterprises in the 1990's," USA-ROC Joint Business Conference, Taipei, December 1992, substantial input from Dr. Mike Kelley, GIT-MARC.
3. Adams, J.C., "Agile Manufacturing Opportunities in the U.S. Apparel Industry," presented to DoC Undersecretary of Science and Technology: Dr. Robert White, Washington, DC, October 1992.
4. Adams, J.C., "Potential Research Topics on DoD Quality Issues," DLA Quality Symposium, February 1992, coauthor.
5. Adams, J.C., "The Apparel Advanced Manufacturing Technology Demonstration Program: A Department of Defense Initiative," Technology Transfer Society Annual Meeting, Denver, CO, June 1991, coauthor.
6. Adams, J.C., "Horizons in Apparel Manufacturing: Computer Simulations of the Apparel Plant," Clothing Manufacturers Association Annual Meeting, New York, NY, May 1991.
7. Adams, J.C., "Transferring Discrete Simulators to Industry," DLS Annual

Researchers Conference, Clemson, SC, February 1991.

8. Adams, J.C., "University Programs for Stimulating Technology Transfer,"  
Technology Transfer Society Annual Meeting, Dayton, OH, June  
1990, coauthor.
9. "The Customer Is Always Right" Apparel Industry Magazine, (April 1989)
10. "New Task for the Computer: Making Clothes" New York Times, (24 January  
1989)
11. "Apparel Manufacturing Technology Center," Apparel Research Committee,  
Raleigh, NC, February 1988, author, Winter Meeting.
12. "Advanced Apparel Manufacturing," Federal Contractors Spring Meeting,  
Miami, FL, March 1988.

**AMTC Quarterly**

"Model of the Manufacturing Process"

By: Sundaresan Jayaraman

Status: published August 1988

**AMTC Quarterly**

"Apparel Manufacturing Architecture: The Function Model"

By: Sundaresan Jayaraman

Status: published May 1989

**ASTM Standardization News**

By: Bonnie Lann

**Computer Aided Problem Solving for Scientists and Engineers**  
Book published by McGraw-Hill Publishing, New York

By: Sundaresan Jayaraman

Status: to be published in late 1990

**Human Aspects of Advanced Manufacturing**

"Human Factors in Advanced Apparel Manufacturing"

By: Mike Kelly

Status: published August 1990

**International Journal of Clothing Science and Technology**

"Discrete Event Simulation of Trouser Manufacturing"

By: Jude Sommerfeld and Wayne Tincher

Status: submitted April 1990

**Journal of the Textile Institute**

"Designing a Textile Curriculum for the 90's: A Rewarding Challenge"

By: Sundaresan Jayaraman

Status: accepted Sept. 1989

**Proceedings of the Biennial Symposium on Psychology in DoD**

"Human Factors in the Manufacture of Military Uniforms"

By: Mike Kelly

Status: published April 1990

**Proceedings of the Second International Conference on the Management of Technology**

"Economic Justification of Technology Acquisition"

By: Bill Riall

Status: published 1990

**Proceedings of the International Conference on Textile Education**  
(refereed)

"Designing a Textile Curriculum for the 90's: A Rewarding Challenge"

By: Sundaresan Jayaraman

Status: published April 1989

**Proceedings of the American Society for Engineering Education 1990 Annual Conference**

(refereed)

"Designing the Manufacturing Engineer of the Future: An Educator's Perspective"

By: Sundaresan Jayaraman

Status: published June 1990

**Proceedings of the AMERICAN Society for Engineering Education 1990 Annual Conference**

(refereed)

"Programming and Software Tools: Need for a Synergistic Approach to Computers in Engineering Problem Solving"

By: Sundaresan Jayaraman

Status: published June 1990

**Proceedings of the International Frontiers in Education 1990 Conferences**

(refereed)

"The Challenge of Educating the Engineering Class of 2000"

By: Sundaresan Jayaraman

Status: published July 1990

**Textile Research Journal** (refereed)

"Design and Development of an Architecture for Computer Integrated Manufacturing in the Apparel Industry Part I: Basic Concepts and Methodology Selection"

By: Sundaresan Jayaraman and R. Malhotra

Status: published May 1990



**Textile Research Journal (refereed)**

"Design and Development of an Architecture for Computer Integrated Manufacturing in the Apparel Industry Part II: The Function Model"

By: Sundaresan Jayaraman and R. Malhotra

Status: published June 1990

**Textile Research Journal (refereed)**

Vol. 59, no. 4, pp. 237-243

"Weave Room of the Future Part I - Team Approach to Operations: A Simulation Study"

By: Sundaresan Jayaraman and R. Malhotra

Status: published 1989

**Textile Research Journal (refereed)**

Vol. 59, no. 5, pp. 271-274

"Weave Room of the Future Part II - Monitored Data for Real-Time Resource Allocation"

By: Sundaresan Jayaraman and R. Malhotra

Status: published 1989

**Textile World**

"Materials Handling in the Textile Industry"

By: Sundaresan Jayaraman

Status: published Dec. 1989

## **PUBLICATIONS**

During the past 3 years, AMTC has been featured in more than 35 publications with a total circulation exceeding 5,500,000 readers. These publications include:

Advanced Manufacturing Technology  
Advanced Military Computing  
American Dyestuff Reporter  
Apparel Industry Magazine  
Army Magazine  
ASTM Standardization News  
Atlanta Business Chronicle  
Atlanta Journal and Constitution  
Acworth/Kennesaw Neighbor  
Bobbin Magazine  
Chronicle of Higher Education  
CMS Carrier  
Columbus Enquirer  
Computer Daily  
Daily News Record  
Economic & Industrial Development News  
Georgia Trends  
Georgia Tech Alumni Magazine  
Georgia Tech Focus  
Georgia Tech Research Horizons  
Georgia Tech Whistle  
GTRI Connector  
Gwinnett Daily News  
Industrial Advisor  
Industrial Engineering  
Knitting Times  
Machine Design  
Managing Automation  
Manufacturing Week  
Modern Materials Handling  
R & D 2000 Update  
Southern Tech Today  
Tech Topics  
Textiles International  
Textile Chemist and Colorist  
Textile World News  
Wall Street Journal  
Women's Wear Daily

**APPENDIX E**

**Photographic Record of AMTC**



The W. Clair Harris building houses the demonstration facilities of AMTC. The facility not only offers a complete pilot scale apparel manufacturing facility but also offers a complete textile testing lab, classrooms, and lecture hall facilities.



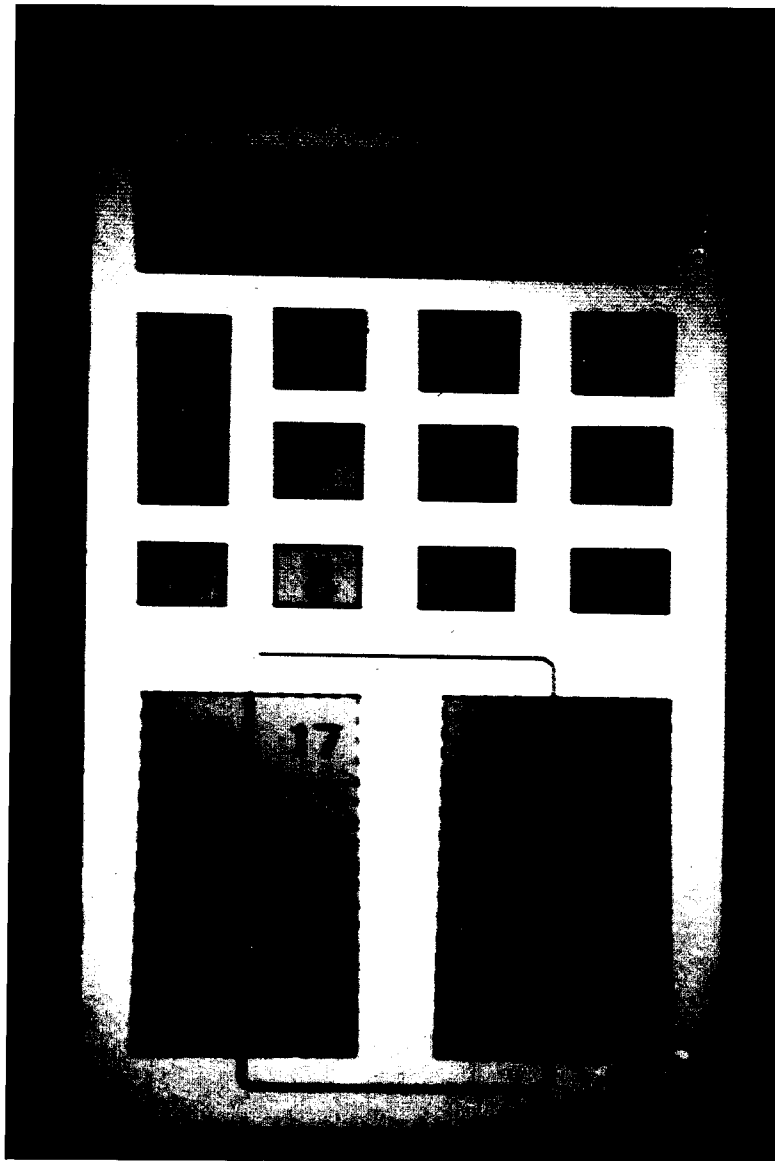
AMTC is a recognized technology leader in BDU trouser manufacturing. The manufacturing demonstration facilities of AMTC are housed within these halls. The main cut and sew hall is shown above. Two other halls are dedicated to CAD marker systems and manufacturing information technology.



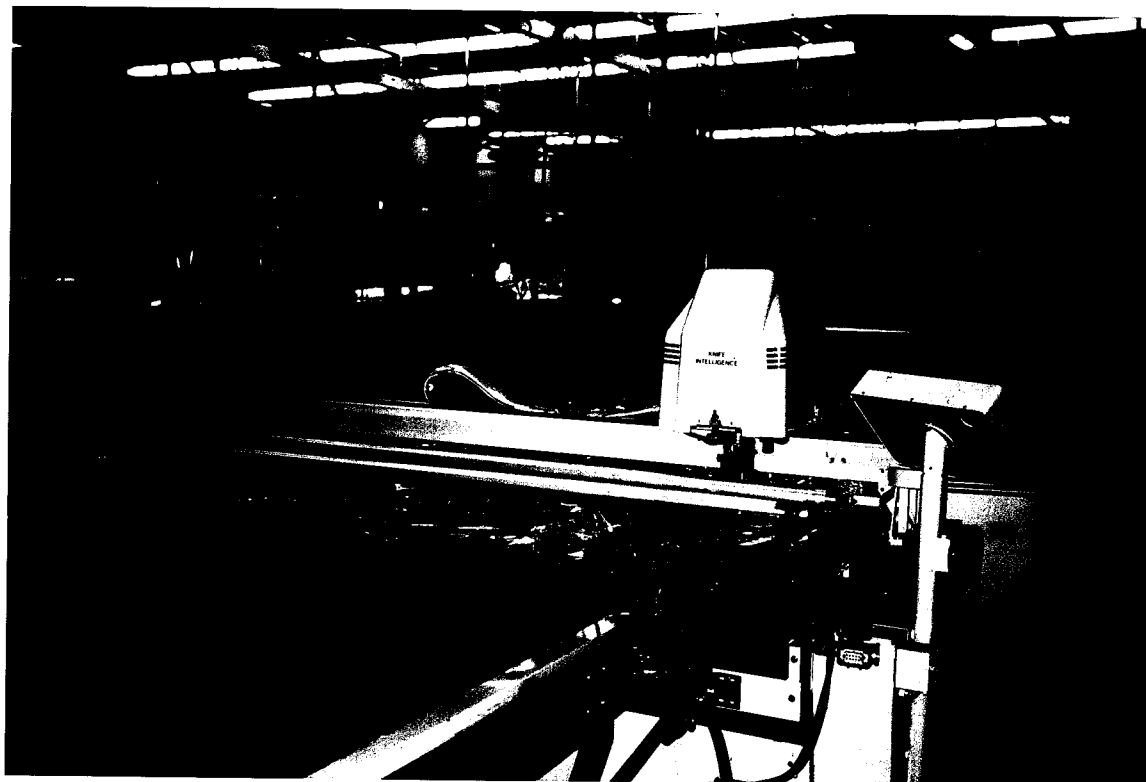
AMTC's sewing operation is composed of a "J" modular unit for two dimensional (flat) sewing and a progressive bundle assembly line (assisted with an automatic materials mover) for three dimensional and felling operations. We believe this arrangement renders the best efficiency for equipment/personnel utilization and low in-process inventory.

Materials handling in the "J" cell is accomplished by utilizing an overhead slick rail/hanger arrangement and one garment bundles.

AMTC's manufacturing concept takes 6 minutes out of assembly standard allowable minutes (SAMs).



The original layout of the sewing operation was not by accident. It was developed by a senior Industrial and Systems engineering design team. Constraints of floor space and available (consiged) equipment were the two primary constraints in the project.



The largest piece of equipment in the sewing hall is the high ply robot cutter. The system has far greater capacity than needed for demonstration purposes. However, it serves as focal point for visiting DOD contractors as cut quality and yield are of primary interest.





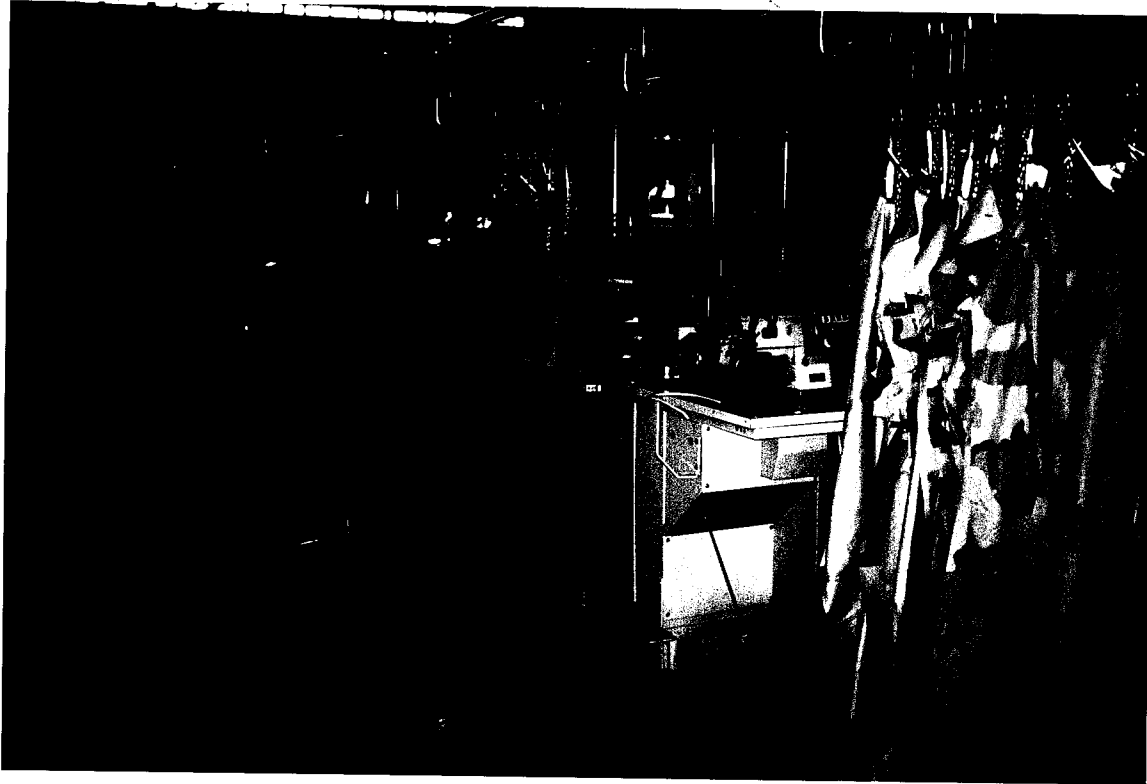
Another major input to AMTC's pilot plant layout and operations is industry. Many of the concepts put into practice in the sewing hall are a result of industry interaction. Frequently industry leaders possess great ideas but do not have a pilot scale manufacturing facility for testing and development. AMTC has been a venue for many of these ideas.



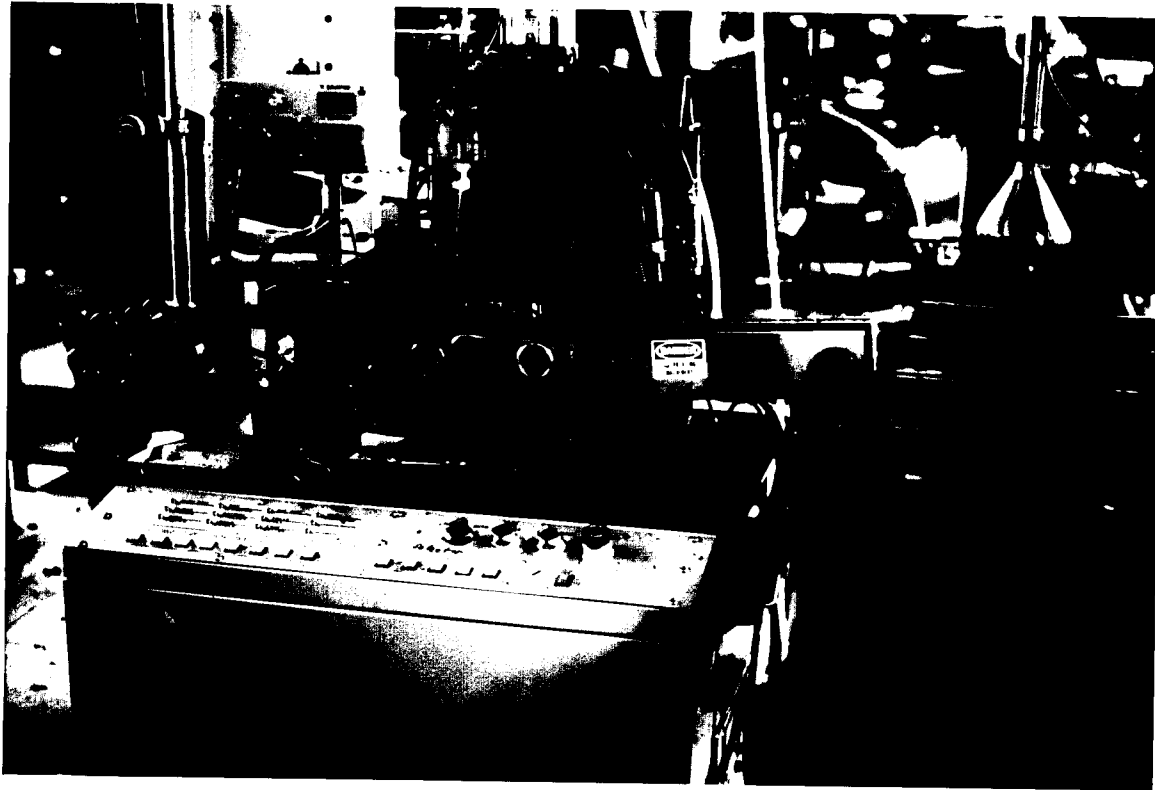
This photograph shows a view of the slick rail arrangement used to handle garments in the two dimensional sewing "J cell" module.



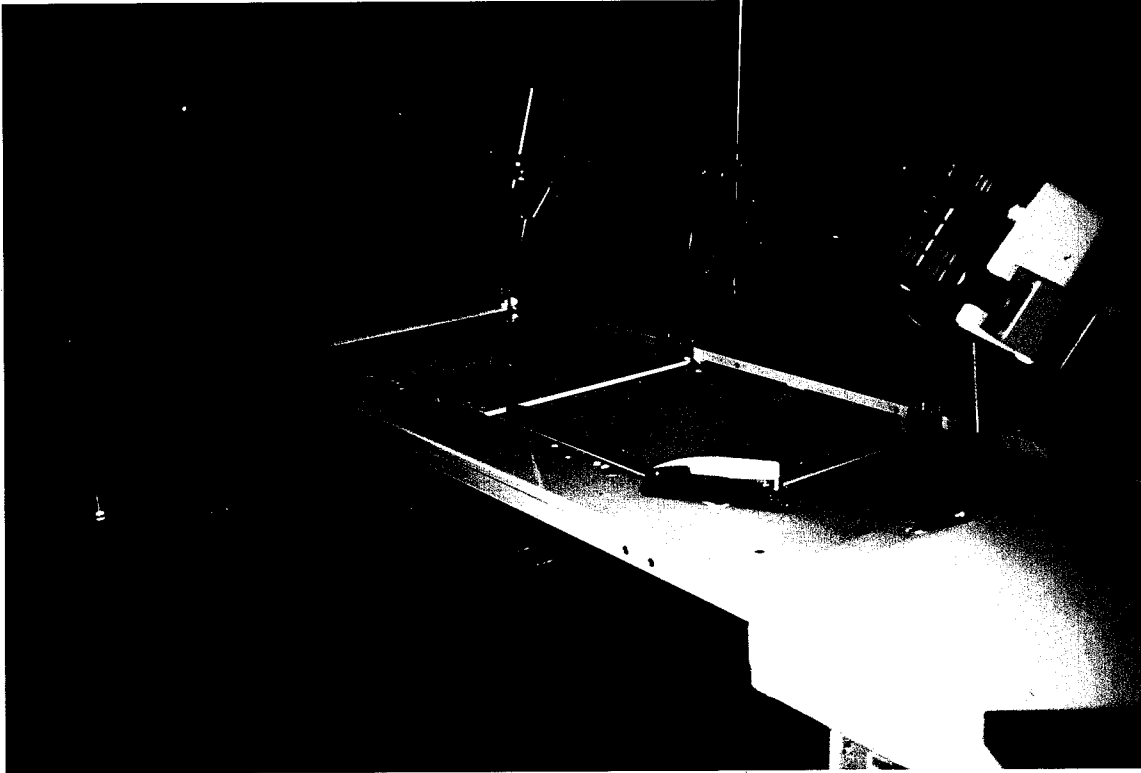
As part of the "J cell" modular system. AMTC developed a novel hanger system. The hanger system holds all the primary components of each BDU trouser in a fashion that enables each bundle of one garment can undergo 17 operations without detaching the garment from the slick rail system.



This view shows the AMTC developed hanger system in its work mode. Note: Most small assembly is performed prior to loading the modular unit. Emerging technology will enable the assembly of small components to be largely performed by handicapped operators and /or automation.



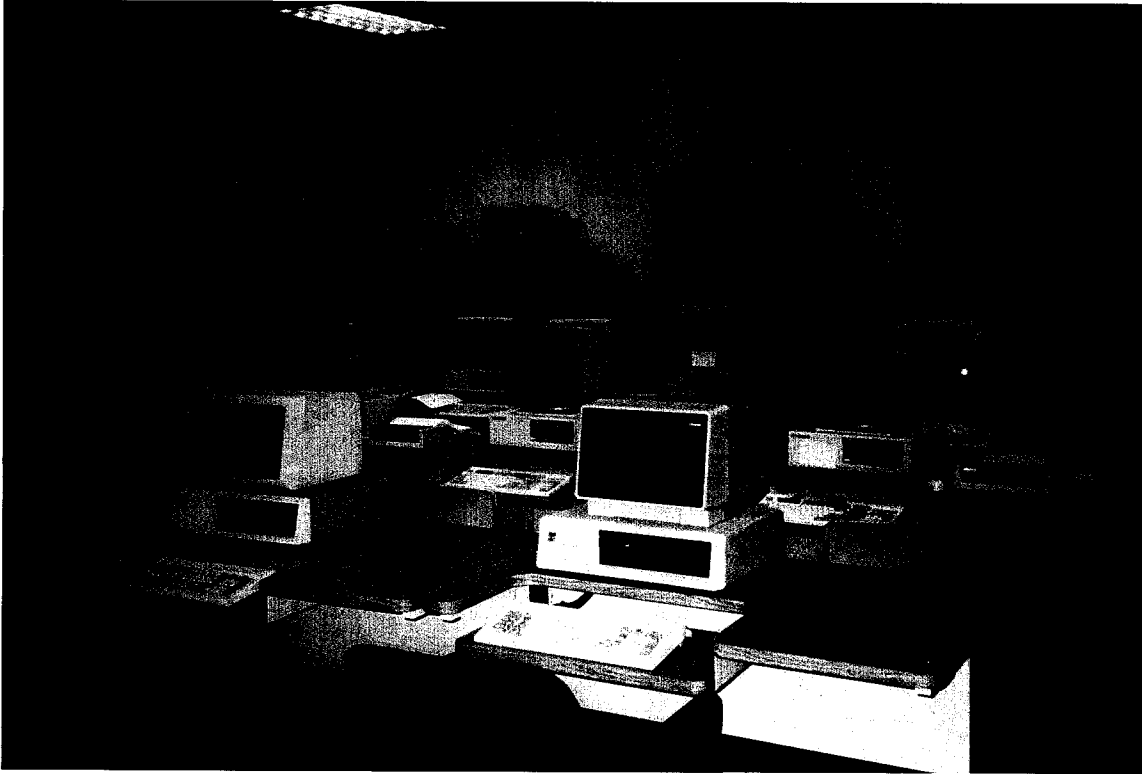
Another sewing room development is the automated zipper assembly sorting system. Developed during the earlier period of demonstrating the Navy utility jean, the device reduces the garment SAM by 35 seconds.



AMTC's sewing unit is brimming with technology. This view shows a Durkopp Programmable flat bed sewer used to attach BDU cargo pockets--This equipment is part of our efforts to utilize existing advanced technology in innovative but sometimes unconventional applications. This particular endeavor provided pilot development for the current automatic cargo pocket setter project.



The heart of AMTC's early manufacturing information systems was two mini computer based systems: an HP 3000 operating HP's MRPII<sup>+</sup> system and an IBM AS400/30 operating the ACS sewing plant system. These systems are now retired as much of the information management is handled by highend PC's.



This view better illustrates the layout of the apparel manufacturing information systems hall. It is laid out in a classroom format, accomodating over 20 seminars/workshops since 1988.

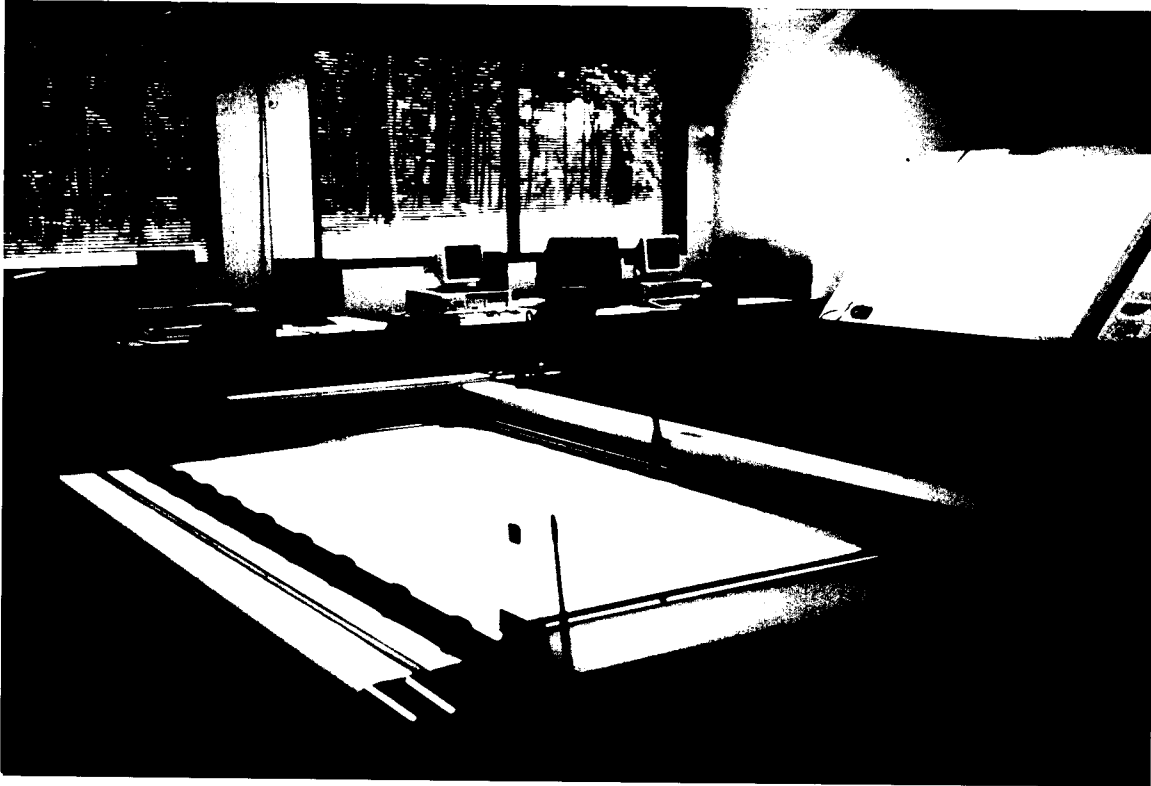




AMTC offers a full apparel design center, including full body scanning, interactive computer design, and color print output. The system has been used for new design prototyping and visualization of suggested design changes to DOD uniforms.



Fashion design remains a popular elective course for Southern Tech's Apparel Manufacturing Engineering students. The broad curriculum at Southern Tech (the only ABET accredited program in the U.S.) provides the industry an excellent venue to advanced technology through recruiting graduates. All major U.S. apparel corporations have senior management from Georgia Tech and/or Southern Tech.



AMTC's pattern CAD systems have been the focus of numerous workshops and plant assistance projects. Although the technology has been available for 20 years, few DOD contractors utilize computerized patterns to plan cuts. These systems offer a tremendous opportunity for DOD contractors to improve fabric utilization (thus better margins through less waste). In the future, CAD systems will be necessary for DOD contractors to accommodate special measurement requirements and diversification to civilian products.

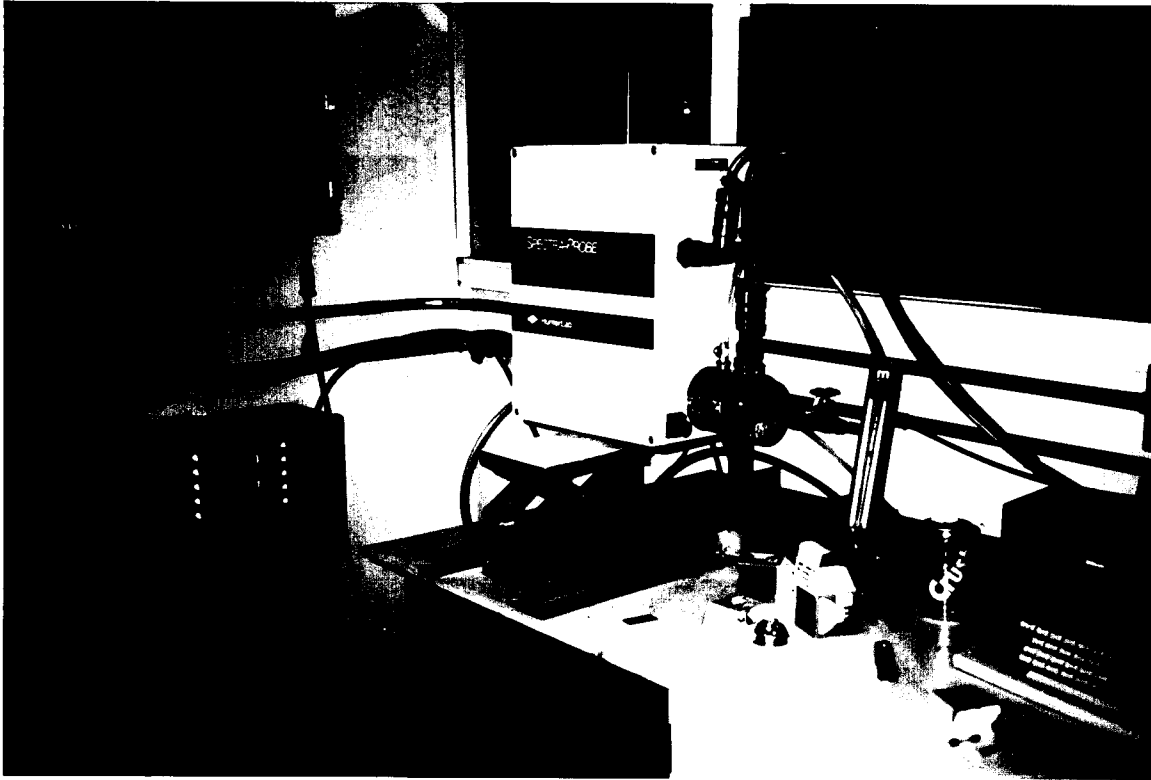


Although AMTC has traditionally focused on trouser manufacturing, we routinely service industry clients who have problems with tops manufacture.



AMTC not only has industry "come to us", but we also participate in industry functions and make regular "house calls" to plant sites.

The following photographs show a series of research projects where AMTC has demonstrated the results. Many of the projects are on-going and have generated substantial industrial interest.

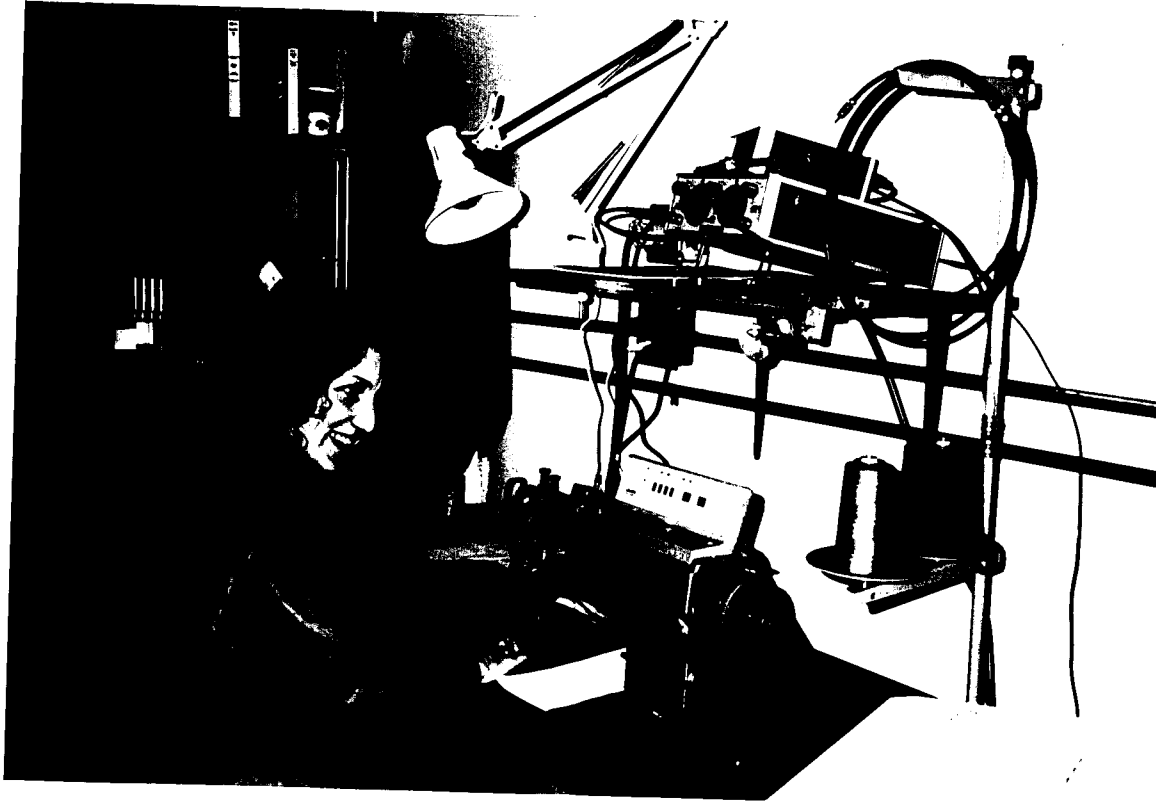


Automatic color measurement and shade matching research has pioneered several new approaches to facilitate matching denim trouser panels. This work supports an initiative to remove fabric defects after cutting. Since most fabric defects are point defects (instead of warp or filler defects), almost 3 yards of fabric is saved per defect by removal of defective fabric panels instead of cutting fabric roll lengths to match cut marker ends. Shade matching enables removal of defective cut parts to be replaced with a shade matched substitute so bundle index integrity is maintained.

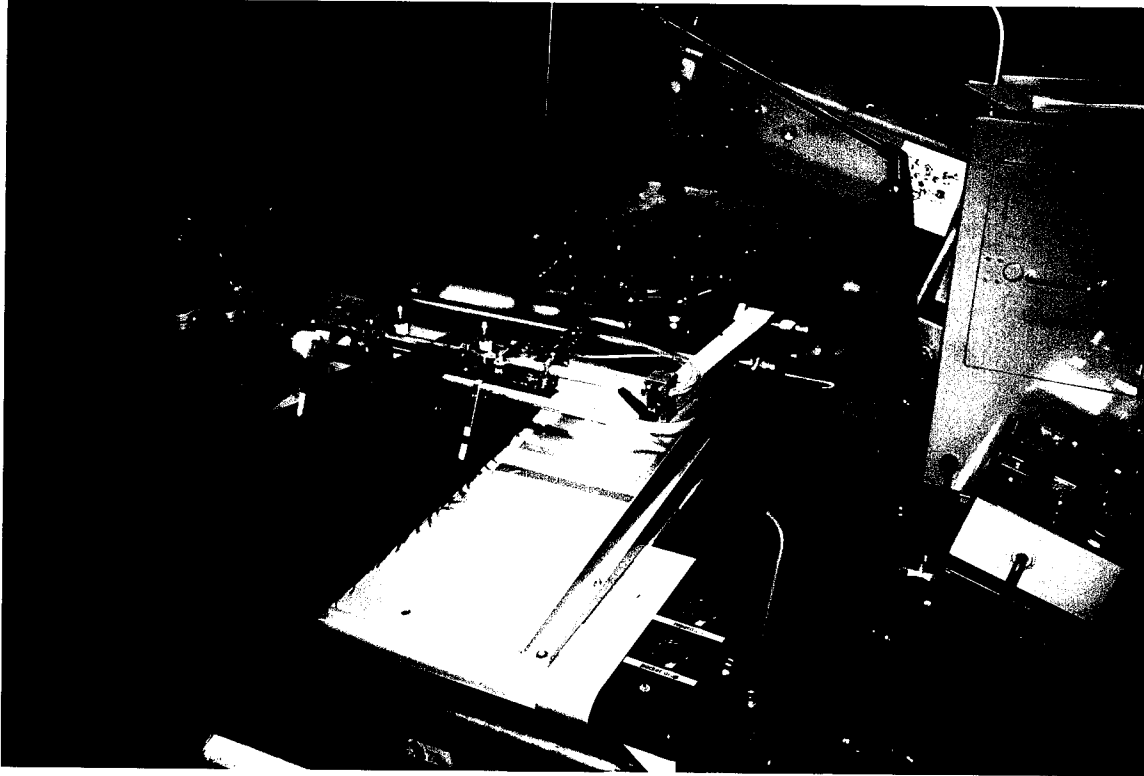


**This view shows the Georgia Tech robotic sewing cell for two dimensional assembly. It was pioneered to automate small parts assembly. The system endeavors to remove the barrier to automation associated with manual loading and positioning required by programmable sewers.**

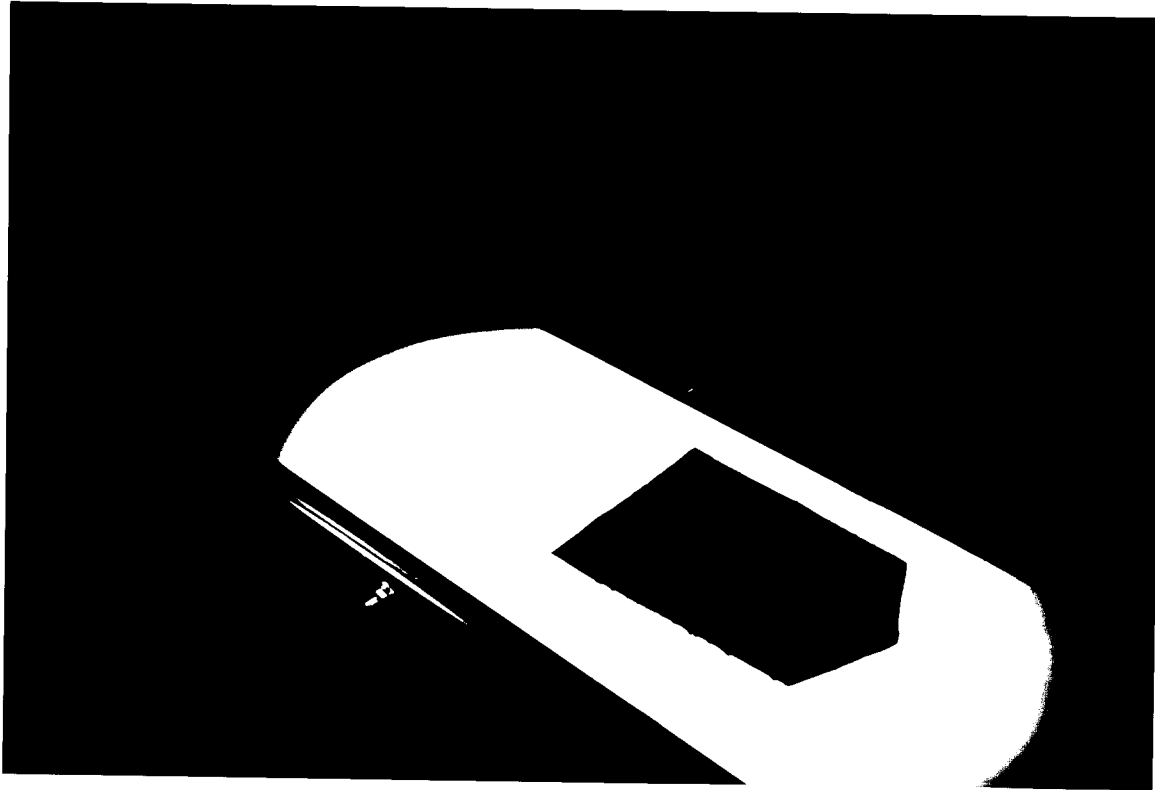




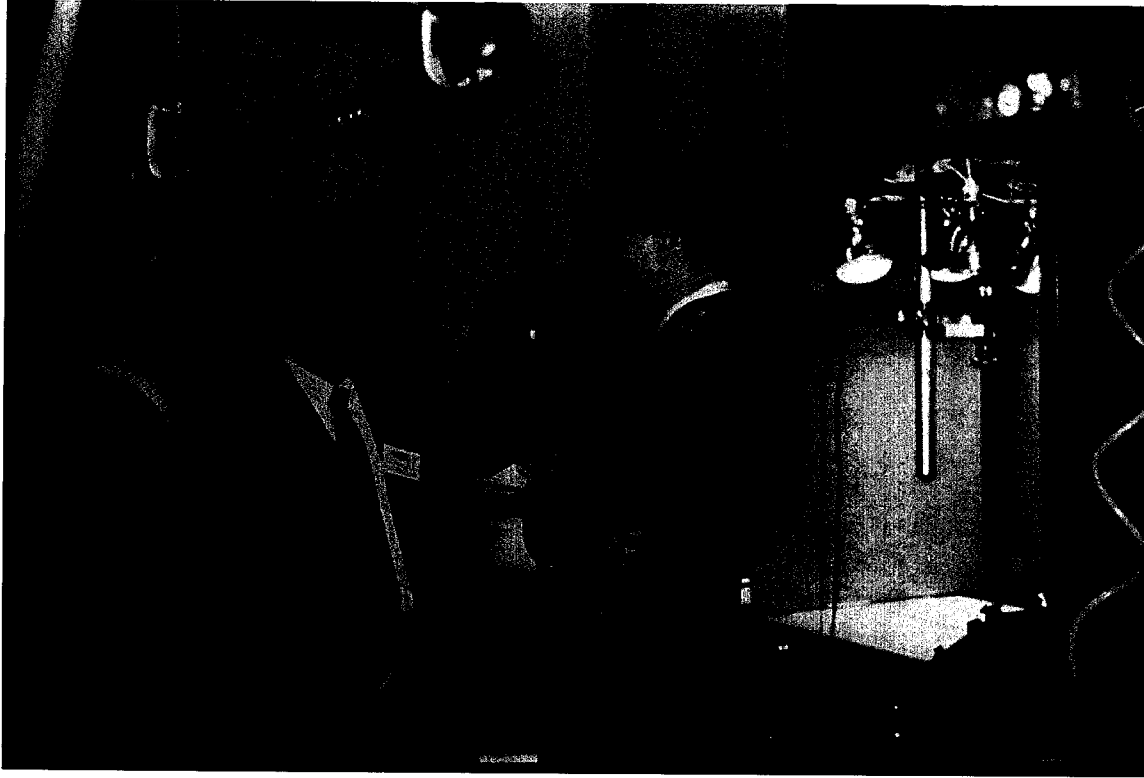
The accoustical sewing fault detection project supports automated sewing research. Georgia Tech envisions the near future to offer fully automated sewing in the two dimensional plane (flat sewing). With several sewing operations coupled without human intervention, sewing fault detection becomes critical. Skipped or missed stitches, as well as thread breaks, must be quickly identified before huge quantities of defective parts are produced. Acoustical surveillance of sewing is a promising technology. In fact, sewing manufacturers are currently embracing the technology on existing plant operated sewing machines to improve quality and reduce rework associated with sewing defects.



**Cargo pocket setting research offers the promise of cost effectively removing over 1.5 SAMS from BDU trousers. Also, the technology will deskill the operation to enable the skilled pocket setter operator to relocate to operations where automation is currently unavailable and high skill is necessary.**



Also, the automatic inspection of cut parts is a needed component for the automated flat panel sewing initiative. This project endeavored to identify the defective parts--supporting the "removed fabric defects after cutting" program. The gray scale vision system integrated in the prototype machine enabled not only automated defect detection but also cut part dimensional integrity inspection.



Automatic cut-part inspection

## **APPENDIX F**

### **Initial AMTC Pilot Plant Design**

**F i n a l   R e p o r t**

**Final Layout Selections of the AAMTDC and Full-Scale  
Facilities**

**Prepared For:**

**John Adams  
Senior Research Engineer**

**Georgia Tech Research Institute  
Economic Development Laboratory  
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**Prepared By:**

**Gordon Connelly  
Angie Jernigan  
Ken Thomas  
Joel Wood  
John Wooten**

**ISyE 4105 - Senior Design Group 11**

**Spring Quarter 1988**

**May 23, 1988**

Georgia Tech  
Box 33075  
Atlanta, GA 30332

May 23, 1988

Mr. John Adams  
Research Engineer  
Georgia Tech Research Institute  
Economic Development Laboratory  
O'Keefe Building  
Atlanta, GA 30332

Dear Mr. Adams:

Accompanying this letter is the final report for the project which was entered into by Senior Design Group 11 in January of this year.

This report contains: the final layout selections for both the AAMTDC and the full-scale facility, the criteria that were used to make those selections, and an analysis of the over-all selection process.

We appreciate the time and energy you have spent as the sponsor of this project and look forward to seeing the final implementation of our designs. If you have any questions regarding this report or any other portion of our work, please feel free to contact us at any time.

  
Gordon Connolly

  
Angie Jernigan

  
Kenneth Thomas

  
Joel Wood

  
John Wooten

## TABLE OF CONTENTS

### Executive Summary

I.	Introduction.....	1
	A. Description of Organization.....	1
	B. Problem Description.....	3
II.	Objective of Design Project.....	5
III.	AAMTDC.....	6
	A. Scope of Design Project.....	6
	1. Boundaries	
	2. Constraints	
	3. Assumptions	
	B. Approach Followed.....	8
	1. Education	
	2. Analysis of Project	
	3. Generation of Alternatives	
	4. Selection of Best Alternative	
	C. Alternative Layouts.....	13
	1. Equipment Standards	
	2. Equipment Assumptions	
	3. Generation of Alternatives	
	D. Alternative Layout I.....	16
	1. Overview	
	2. Material Routing	
	3. Observer Flow	
	4. Aesthetics	
	E. Alternative Layout II.....	18
	1. Overview	
	2. Material Routing	
	3. Observer Flow	
	4. Aesthetics	
	F. Alternative Layout III.....	20
	1. Overview	
	2. Material Routing	
	3. Observer Flow	
	4. Aesthetics	
	G. Alternative Layout IV.....	21
	1. Overview	
	2. Material Routing	
	3. Observer Flow	
	4. Aesthetics	
	F. Evaluations of Alternatives.....	22
	1. Weighted Averages	
	2. Pair-Wise Elimination	
	G. Selected Layout.....	26



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May 23, 1988

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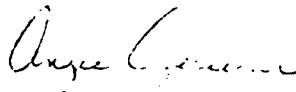
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John Wooten

## Executive Summary

In the following report Senior Design Group 11 will present a layout for the Apparel Advanced Manufacturing Technology Demonstration Center (AAMTDC) and an illustration of how the state-of-the-art equipment used in the AAMTDC can be employed in the full-scale layout.

In developing this layout, the scientific method was used to arrive at the proposed alternative. All decisions that were made throughout the developmental process were based upon: the information Senior Design Group 11 received from the administration and apparel industry experts, the criteria that was prescribed by the AAMTDC administration, and standard engineering practices.

The development of the full-scale layout was based on an identical approach; however, it was not constrained by space requirements but was instead primarily based upon criteria.

Senior Design Group 11 offers these layouts as feasible and effective contributions to the AAMTDC project effort.

H.	Implementation Information.....	28
	1. Material Handling Suggestions	
	2. Location of CAD/CAM Room	
	3. Work-In-Process Levels	
IV.	Full-Scale Facility.....	34
	A. Scope of Design Project.....	34
	1. Boundaries	
	2. Constraints	
	3. Assumptions	
	B. Approach Followed.....	35
	C. Quantitative Evaluations.....	36
	1. Buggy System	
	2. UPS System	
	3. UPS with Buggy System	
	D. Qualitative Evaluations and Selection....	42
	1. Buggy System	
	2. UPS System	
	3. UPS with Buggy System	
V.	Time Spent on Report.....	48
VI.	Conclusion.....	49

## I. Introduction

This report represents a concise and comprehensive explanation of the problem at hand, the methods used to solve the stated problem, and finally a detailed solution which Senior Design Group 11 feels is the most viable solution to the problem. Some of the information has been duplicated from previous reports. However, this report has been created to summarize all efforts and results which have been achieved by Group 11 from January 9, 1988 until May 16, 1988.

### A. Description of Organization

The Georgia Tech Research Institute (GTRI), in conjunction with Georgia Tech's School of Textile Engineering and the Southern College of Technology, has been contacted by the United States Defense Logistics Agency (DLA) to design and operate an Apparel Advanced Manufacturing Technology Demonstration Center (AAMTDC). This demonstration center will also double as a research center and will be located on the Southern College of Technology campus. Industry will provide all necessary equipment, and during the demonstrations, will supply employees to help supplement the normal workforce of Southern Tech students and faculty members.

The primary goal of the center is to assist apparel manufacturers in evaluating advanced manufacturing technology and in adopting state-of-the-art management

## List of Figures

<u>Name</u>	<u>Figure</u>
Precedence Chart ....	1
Unit Production System .....	2
Alternative 1 .....	3
Alternative 2 .....	4
Alternative 3 .....	5
Alternative 4 .....	6
Demo Center .....	7
Visitor Routings .....	8
Quantitative Summary .....	9
Buggy System .....	10
Alternative 1 .....	11
Alternative 2 .....	12
Alternative 3 .....	13
Qualitative Summary .....	14
Unit Production System .....	15

## Calculations

Cost Estimation Calculations .....	16
------------------------------------	----

techniques to improve their productivity. The federal government feels that the costs of domestic apparel suppliers are unnecessarily high and that American industry is losing markets to foreign competition. As a result, the apparel manufacturing capacity of the United States is decreasing. This could place America in an undesirable position should a war-time situation require a large output from domestic suppliers of military apparel.

## B. Problem Description

The danger to the American apparel industry is real. The difference in labor wages is the primary problem. Even with shipping and other costs associated with manufacturing abroad, it is still often less expensive for manufacturers to produce their apparel products overseas. Unless this difference in labor wages can be somewhat offset by introducing new technology and techniques into the American apparel industry, the United States will continue to lose more and more of the apparel market to foreign competition.

To effectively demonstrate the machinery and techniques, the center, employing the design we are submitting, will actually produce a product. This will enable visitors to view the the entire process from raw materials to finished product. The center will initially focus on producing military trousers, but will also be a location to perform research and demonstrate technologies to more cost effectively produce civilian garments. (Group 11 solely focused on producing the men's trousers.)

As a result, a full-scale production layout, utilizing the same technologies, machines, and management techniques used in the center, will be made available to the visitors of the demonstration center. This "future-plant" will represent the direction which the government hopes the American apparel industry will head. The

plant, unlike the demonstration center, will have balanced lines of production and will be laid out to achieve maximum efficiency and output.

John Adams, director of the AAMTDC effort, along with Professor Larry Haddock and Dr. Wayne Tincher supplied necessary general and technical information regarding the manufacturing process and the demonstration center site. Scott Hall, plant manager of the Lee plant in Jasper, Georgia, provided the bulk of the information which was needed in order for the project to be completed on time by Group 11.



## II. Objective of Design Project

The objective of ISyE Senior Design Group 11 was two-fold. First, a production layout for the Apparel Advanced Manufacturing Technology Demonstration Center (AAMTDC) had to be generated. It was designated that this layout must be functional for demonstrations and must operate within the physical constraints of the existing building. Second, an full-scale production design and layout was requested. This design was to encompass a modernized manufacturing processes based on given production requirements and was not constrained by space. Therefore, this full-scale production layout will be used by center personnel to generate actual production, manpower, and cost data for use in the industry demonstrations that will take place at the AAMTDC. The actual demonstration layout of machines and material handling equipment will be used for production demonstration purposes only.

### III. AAMTDC

#### A. Scope of Design Project

##### 1. Boundaries of Project

In generating the AAMTDC design, general guidelines were used to determine how the machines and the unit production system ( UPS ) would be configured. These guidelines were based on an analysis of material flow, space requirements, OSHA requirements, observer flow, and material handling requirements. Cost elements were not considered a limiting factor, because such information was not provided to Group 11.

The goal in developing this layout was to provide our client with an efficient use of space, while maximizing the opportunity for the machinery to be viewed in a working process. The final layout selected was to provide smooth production and material flows and be aesthetically pleasing.

##### 2. Constraints of Project

Several constraints had to be addressed in the design of the AAMTDC layout. These constraints included:

- a. A humidity and temperature controlled room which exists in the building and cannot be relocated. This room restricted the determination of the placement of storage areas, computer facilities, and other support

areas for the demonstration area.

b. After the implementation of the layout, several pieces of equipment will be immovable. These machines include the spreader/cutter, the central processing units ( CPUs ), computer terminals, and computer consoles. Therefore, the final layout must be completely feasible in its final form.

c. The most difficult constraint to work around was the initial unavailability of machine specification data. Since finalized machine specifications were not provided by the originally set deadlines, approximate specifications were gathered from the Lee Jeans Plant in Jasper, Georgia.

### 3. Assumptions of Project

In developing the AAMTDC layout, a number of major assumptions were made. These assumptions included:

a. The existing building is adequate for the design purposes with regard to electricity availability, plumbing facilities, and ventilating capacity.

b. All manufacturing and material handling equipment was to be selected by the AAMTDC administration. As mentioned previously, this assumption was abandoned and approximate specifications were used in order to meet

completion deadlines. Group 11 also reserved the right to make material handling suggestions.

c. Group 11 would not be involved in designing or implementing production database applications.

d. The manufacturing methods and machine capabilities are similar to those at the Lee Jeans Plant in Jasper, Georgia.

e. Group 11 was only deemed responsible for the following:

- i. the placement of process and material handling machinery.
- ii. determining the location for raw materials, work-in-process, and finished goods.
- iii. the placement of the computer room ( CAD ).

## **B. Approach Followed**

The scientific method was the basic approach used to systematically determine the final layout for the AAMTDC. However, prior to the definition phase, the group had to educate themselves on the processes, machinery, and products that were involved in the project.

### **1. Education**

#### **a. Product**

A specification sheet was provided, which outlined the requirements for the denim utility trousers used by the United States Department of Defense.

b. Process

i. Production Flow

- Visited the Lee Jeans Plant in Jasper, Georgia several times to gain an understanding of how the production process works.
- Attended lectures at Georgia Tech presented by Professor Larry Haddock. Professor Haddock's lectures concerned innovations used in today's apparel manufacturing facilities.
- Learned the processing steps of the utility trousers as outlined in the Georgia Tech Research Institute Operational Proposal.

ii. Equipment

- Attended material handling and machinery equipment demonstration sessions presented to the AAMTDC Research Team by local apparel equipment manufacturers.
- Learned an extensive amount about machine sizes and capabilities from Scott Hall, Plant Manager of the Lee Plant in Jasper, Georgia. He also provided valuable insight used to solve problems which arose throughout this project.
- Used the literature search equipment of the Economics Development Laboratory. By using key words and dates, the Basic Data Department at the Georgia Tech Research Institute retrieved articles dealing with developments in the apparel industry and techniques used with state-of-the-art equipment.
- Professor Haddock verified that the machine specifications and material flows, which were used to generate a production layout, were correct.

**2. Project Analysis**

In analyzing this project, seven distinct steps were performed. They included:

a. Gathering approximate specifications on equipment for the AAMTDC, including:

- i. footprint dimensions
- ii. operation processing dimensions
- iii. equipment dimensions
- iv. material feed orientation

- v. production efficiency ratings
- b. Determining the process flow between equipment types.
- c. Determining the process flow within each workstation.
- d. Gathering the specifications on the unit production system ( UPS ).
- e. Determining the amount of space required to store work-in-process.
- f. Determining observer flow.
- g. Gathering information on pertinent OSHA safety requirements.

The data from these seven steps was organized and used to strategically and tactically plan the alternative layouts.

### 3. Generating Alternatives

The criteria used to generate alternatives was specified by the, AAMTDC administration. Because of various uncertainties surrounding the project, the criteria was not weighted at the time the alternatives were generated. Therefore, the various layouts were generated by altering the prioritization places on the following criteria:

#### a. Aesthetics

The AAMTDC must be aesthetically pleasing to the eye. Because the observers will likely be skeptical of the new technology, every effort must be made to make a favorable impression on them.

#### b. Material Flow

The proper material flow was determined using precedence diagrams and flow charts. A smooth material flow will add to the effectiveness of the demonstrations.

#### c. Observer Flow

The proper observer flow was determined by designing the shortest and safest path the observer would have to take to view the entire process in operation.

#### d. Space Requirements

The space requirements were determined according to machine dimensions and the space needed for machine operators, storage areas, observers, and material handling equipment. These requirements were obtained from the approximate machine and equipment specifications, desired inventory levels, manual data collection from the Lee Jeans Plant, and OSHA safety standards.

#### 4. Selecting Best Alternative

After several administrative decisions, Professor Haddock was able to advise us on how the criteria was to be weighted. Out of 100%, they were weighted as follows:

Aesthetics	50%
Material Flow	30%
Observer Flow	20%
-----	----
Total	100%

It should be pointed out that for a layout to be considered, it had to meet all space requirements.

The selection process was done in two stages. In the first stage, all layouts were scored according to a weighted average method based on the above weights (This will be explained more explicitly later ). The layout with the highest score was chosen as the best. Secondly, the layouts were compared in a pair-wise manner, according to each of the weighted criteria. This process was repeated until the layouts were ranked in each category. The layouts were then scored based on the weightings, and the layout with the highest score was chosen as the best ( This will also be explained more explicitly later ).

While both of these methods yielded the same result, as they should, the dual selection method was necessary to insure accuracy.



PRECEDENCE CHART

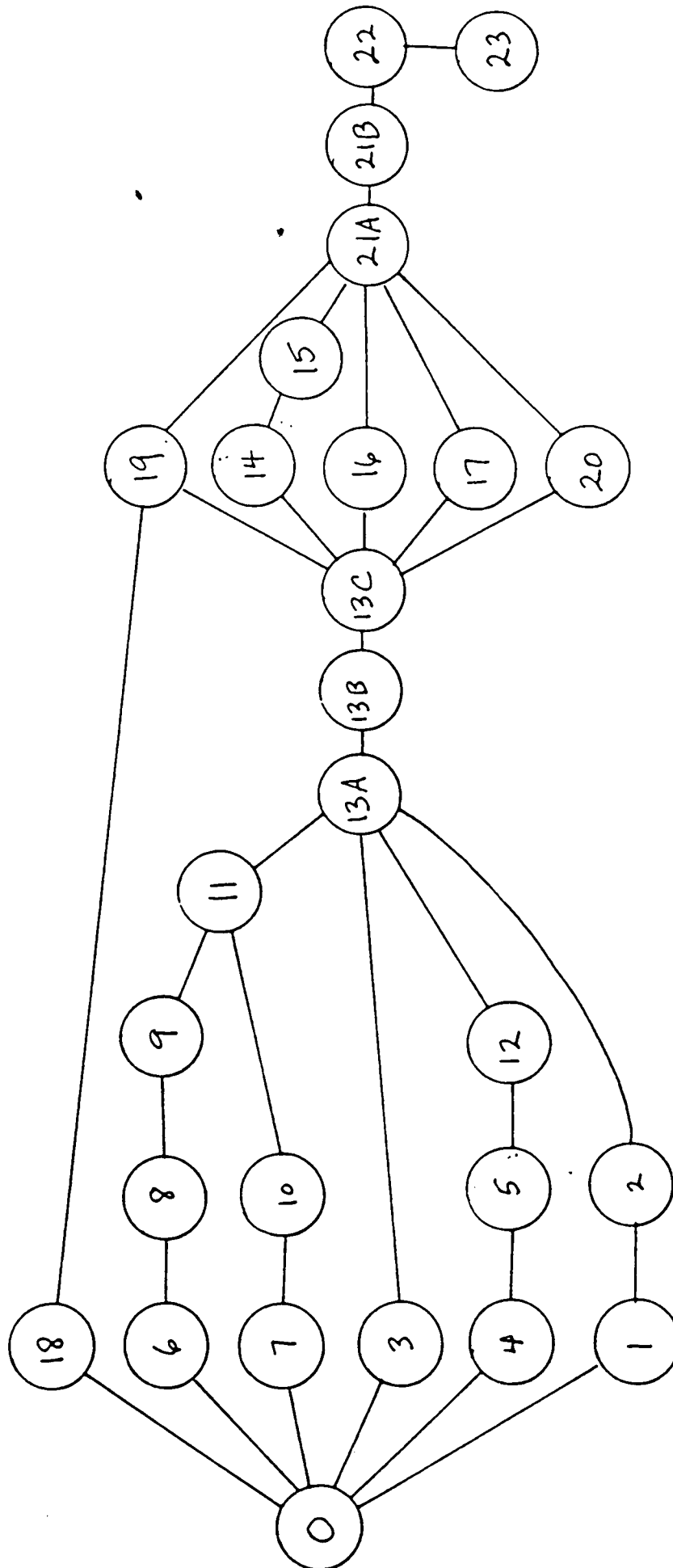


Figure 1

## C. Alternative Layouts

### 1. Equipment Layout Standards

Prior to generating an equipment layout for the AAMTDC, analysis was completed in the following areas:

- a. Possible integrations of processing equipment through the use of:
  - i. Precedence Charts (Figure 1)
  - ii. Methods Time Measurements (MTM) Charts
- b. OSHA Safety Requirements concerning:
  - i. Aisleways
  - ii. Electronic Equipment Clearances
- c. Strategic Use and Placement of Material Handling Equipment for:
  - i. Material (Finished, In-Process, and Raw) Storage/ Retrieval
  - ii. Inter-workstation Routing
  - iii. Intra-workstation Routing
- d. Determine Space/Room Allocation for Materials through analysis of:
  - i. Expected Raw Material Inventory Levels
  - ii. Work-In-Process and Finished Goods Levels (Based on a demonstration time of one hour.)
  - iii. Clearances Necessary for Material Handling Equipment

### 2. Equipment Layout Assumptions

- a. A layout must meet space requirements in order to be considered a viable alternative.
- b. A six foot wide aisle must be provided along the two axis two walls of the building. This provides an unobstructed throughway for personnel in case of an emergency (OSHA).
- c. A "complex material handling movement" will be defined as a movement of material by a means other than a manual or buggy movement.
- d. The equipment layouts meet all precedence relationships as outlined earlier in Figure 1.
- e. The layout of all UPS equipment will be standard on each layout according to Figure 2. Therefore, the UPS system will simply be represented by a large

# UNIT PRODUCTION SYSTEM

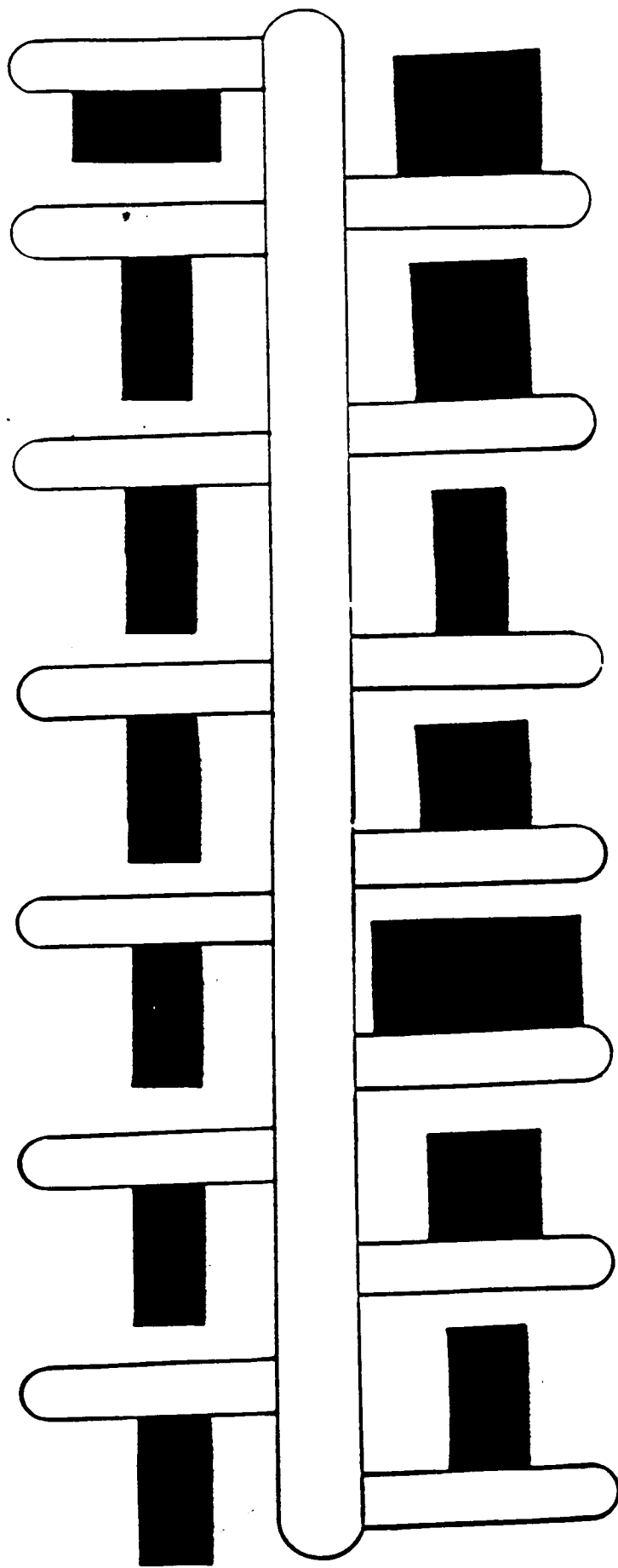


Figure 2

42.8'x15.5'

"processing block" appearing on each alternative layout.

- f. Room for work-in-process was calculated for each alternative and the necessary amount of room was left around each workstation for tables to hold any goods in queue. This enables the center to operate for an hour long demonstration without any idle or bottlenecking delays.
- g. Due to the type of processing which will be performed in the the subassembly area, the bundles of material will be passed on to subsequent workstations manually. (This was discussed and determined during the May 5th meeting between Group 11 and Professor Larry Haddock.) Buggies would not enhance the center aesthetically.
- h. Subassembly equipment will reference those machines which are not located on the Unit Production System (UPS). These machines perform subassembly sewing operations on a two-dimensional plane.
- i. Assembly equipment will reference those machines which are located on the UPS. These assembly machines perform sewing operations on a three-dimensional plane.

### 3. Generating Alternatives

Due to the guidelines set forth in the previous section, there were a limited number of ways the demonstration center layout could be arranged. Altering the location of the spreader/cutter and the six foot safety aisle were the basic means of achieving new layouts. Therefore, the four layouts which are the most feasible are:

Alternative I : Aisle at window/ Cutter at window  
Alternative II : Aisle in middle/ Cutter at window  
Alternative III: Aisle in middle/ Cutter in back  
Alternative IV : Aisle at window/ Cutter in back

Each of these layout schemes use manual material handling in the subassembly area and are capable of having the materials transported from the subassembly area to the assembly area via either a conveyor system or buggies. Since cost was not determined to be a limiting factor, the viability of both of these options will be outlined in Section E - "Material Handling Options".

The material routing path and direction will be designated with dashed lines and arrows. (----->) Observer flow will be highlighted in red.

#### D. Alternative Layout I

##### 1. Overview: Aisle and Cutter at Windows

- i. Raw materials are moved from the storage area via a front loading lift truck to the cutter/spreader. (Note that 10 ft. is needed in front of the cutter/spreader so that the lift truck can turn around.)
- ii. After cutting, the WIP material enters an inverted Z-shaped subassembly arrangement. Subassemblies begin at machines 1, 7, 4, and 6 and are completed at machines 3, 18, and 8 according to the flow pattern on Figure 3. The bundles are then moved from the subassembly area to the sorting area on the UPS.
- iii. The bundles are separated into individual units at the sorting area; the units are loaded onto the UPS; the assembly and finishing operations are carried out.
- iv. The finished goods are unloaded from the UPS and taken to the storage area via a buggy.
- v. The six-foot safety aisle covers the length of the building and lies against the wall that separates the hallway from the manufacturing area. (Note that the cutter is 9.5 ft away from the glass because the doorways protrude 3.5 ft into the room)

##### 2. Material Routing

- i. The only "complex material handling movement" occurs when the fork truck carries the rolls of material from the storage area to hoist it onto the spreader/cutter.
- ii. Each processing machine is located adjacent to its successive processing machine. This characteristic provides efficient material flow by limiting both the travel time from one process to the next and the need for additional material handling personnel and equipment.
- iii. There is adequate room for Work-In-Process at each workstation.

##### 3. Observer Flow

- i. During a demonstration, the observers will enter the manufacturing area from the hallway through the

double doors highlighted in red on figure 4. They will then turn right and walk along the outside of the cutter until they return to the doors leading back to the hallway. There is adequate space, however, for the visitors to leave this primary path to view the machines more closely.

ii. The observer flow crosses the material flow pattern in three locations:

(1) Between the cutter and subassembly processes. This will be a highly congested area because two machines that receive input directly from the cutter are located in that area.

(2) Along the same aisle, finished goods will be taken from the UPS to the storage area. This intersection adds to the congestion of the area and raises more questions concerning the feasibility of this observer path.

(3) The observer flow path will cross the area that the lift truck crosses when taking raw materials from storage to the cutter. This presents safety risks because of the small amount of space available and productivity risks because of the cost of inhibiting the production of the cutter.

#### 4. Aesthetics

i. Although viable, this layout does inhibit observers in the hallway from getting a good view of assembly and subassembly processing areas due to the location of the six foot aisle next to the viewing window and the location of the cutter next to this aisle. The subassembly machines are almost 18 feet from the windows. This may inhibit viewers from noticing the machine integration for trying to see the machines themselves.

ii. The actual processing occurring at the workstations will be visible to the observers at the window since workers will not be between the machines and the window.

iii. The direction of the material flow (from left to right) is conducive to demonstrating processing steps.

iv. The viewers will be able to see over the spreader/cutter (approximately 2.75 ft high) and see the processing machinery located behind it.

## E. Alternative Layout II

### 1. Overview: Aisle in Center/ Cutter at Window

- i. Raw materials are moved from the storage area to the cutter/spreader via a fork truck.
- ii. Same as Alternative I.
- iii. The bundles are separated into individual units at the sorting area; the stacks are loaded onto the UPS; the assembly and finishing operations are carried off.
- iv. When the assembly and finishing processes are completed, the finished goods are unloaded from the UPS and taken to the storage area either via the fork truck or buggies.
- v. The six-foot safety aisle covers the length of the building and lies along the wall that is opposite to the wall that borders the hallway.

### 2. Material Routing

- i. Complex material handling - Raw material retrieval to spreader/cutter and from UPS to storage.
- ii. Each process adjacent to its successive process. (See Alternative I)

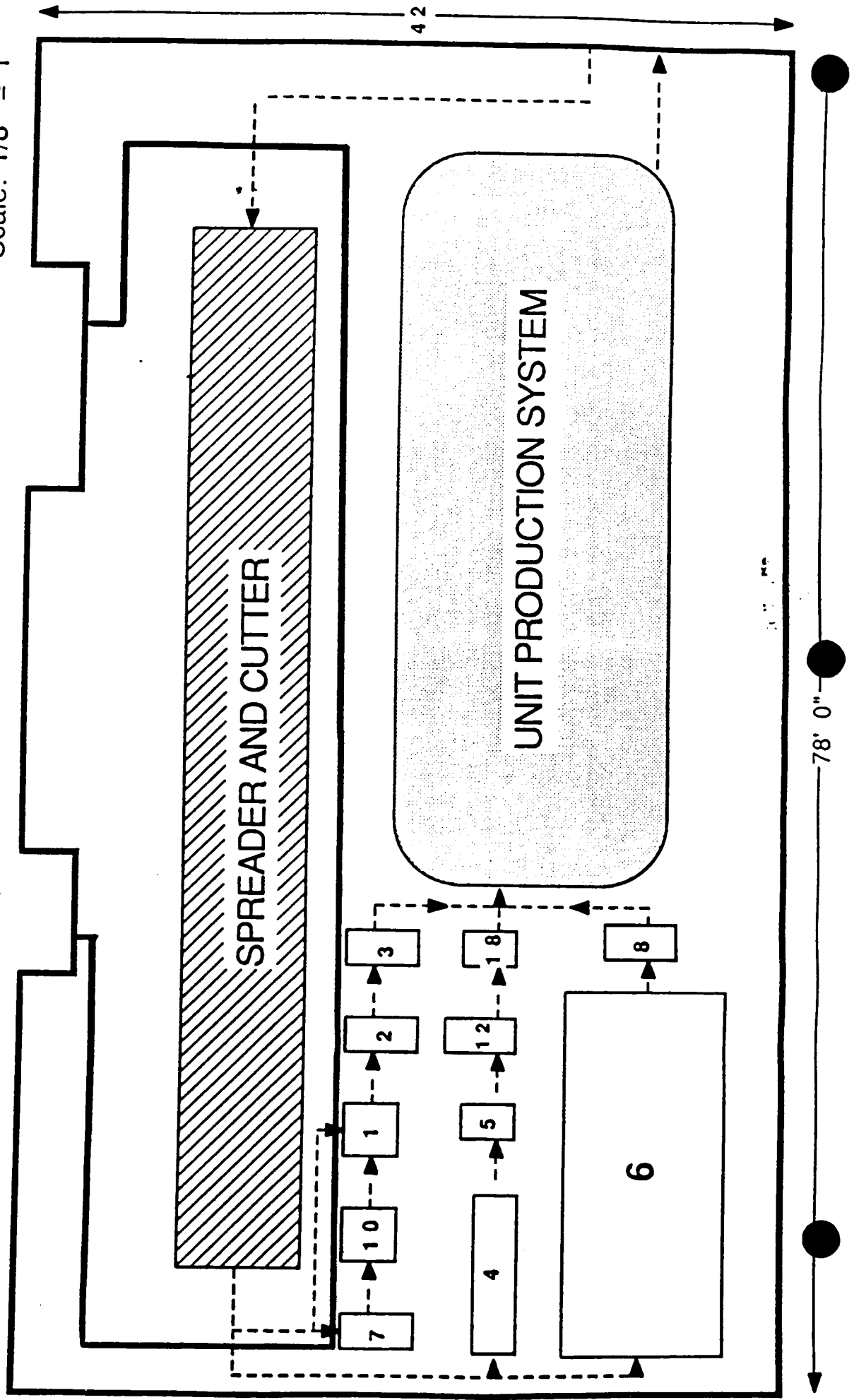
### 3. Observer Flow

- i. During a demonstration, the observers will enter the processing area from the hallway through the double doors highlighted in red on Figure 4. (There will be a clearance of three feet between the doorway and the spreader/cutter.) They will turn right and simply walk along the windowed wall until they reach and proceed down the six foot aisle. (They will basically circle the spreader/cutter.) There is also adequate space for the observers to leave this primary path to view the machines more closely.
- ii. The large aisle between the spreader/cutter makes it easy for a large number of observers to group around a guide during the formal part of the demonstration.
- iii. This observer flow crosses the material flow pattern in two locations:
  - 1) Where raw materials are taken from storage and loaded onto the spreader/cutter.
  - 2) Where the finished goods are unloaded from the



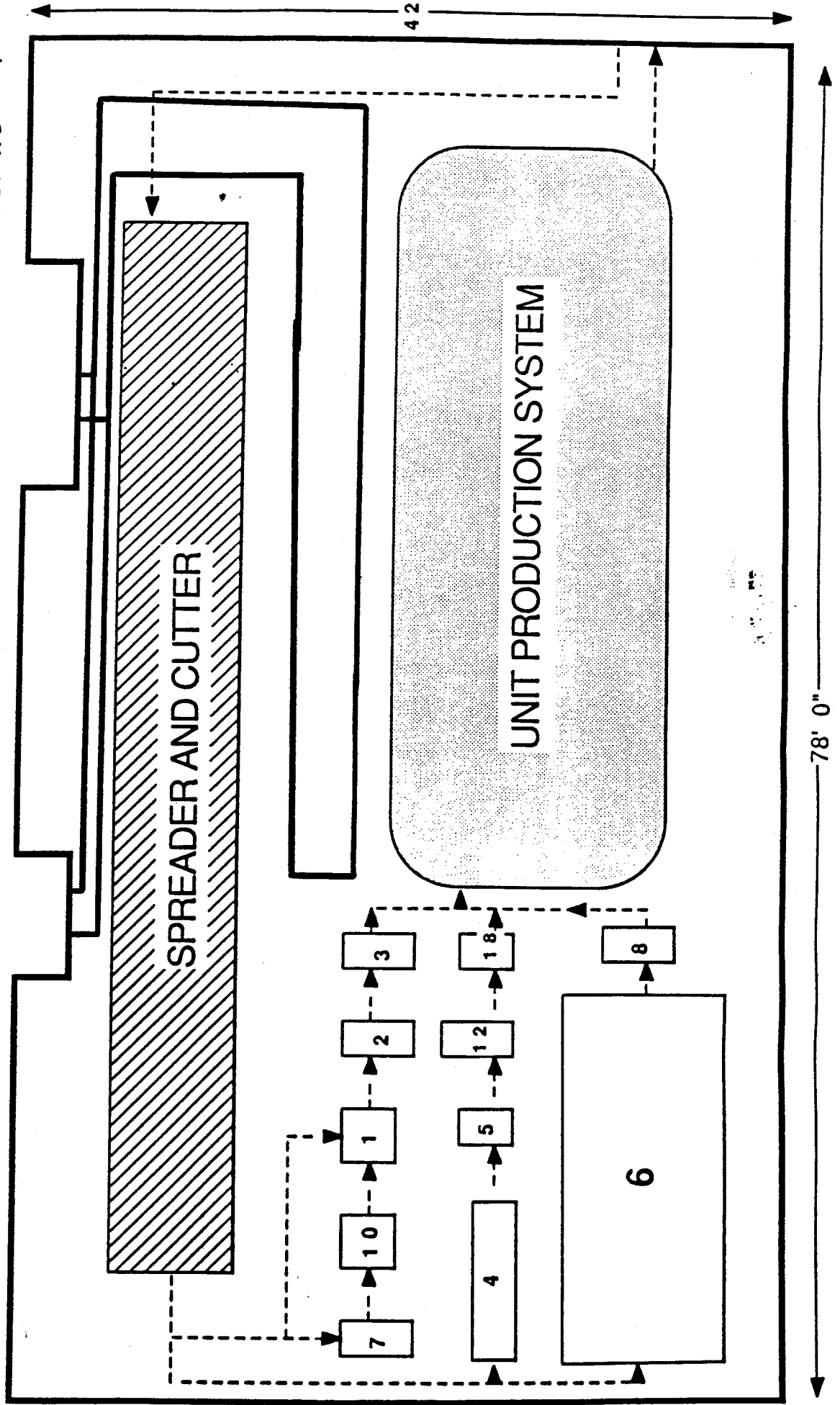
# ALTERNATIVE 1

Scale: 1/8" = 1'



# ALTERNATIVE 2

Scale: 1/8" = 1'



cutter/spreader and sent to the subassembly area.

#### 4. Aesthetics

- i. The spreader/cutter is located near the window. This location will initially grab the attention of the demonstration observers.
- ii. Viewers can see the other processing machines behind the spreader since it is only 2.75 feet high.
- iii. Direction of material flow is conducive to demonstrating processing steps.

## F. Alternative III

### 1. Overview: Aisle in Middle/Cutter in Back

- i. A lift truck will carry raw materials from the storage area to the cutter/spreader.
- ii. Same as Alternative I.
- iii. The bundles are separated into units at the sorting area; the units are loaded onto the UPS; the assembly and finishing operations are carried out.
- iv. The finished goods are unloaded from the UPS and are taken to the storage area by a lift truck.

### 2. Material Routing

- i. The only complex material handling movements occur when the material is transported to and from the storage area.
- ii. Each process is adjacent to its successive process.

### 3. Observer Flow

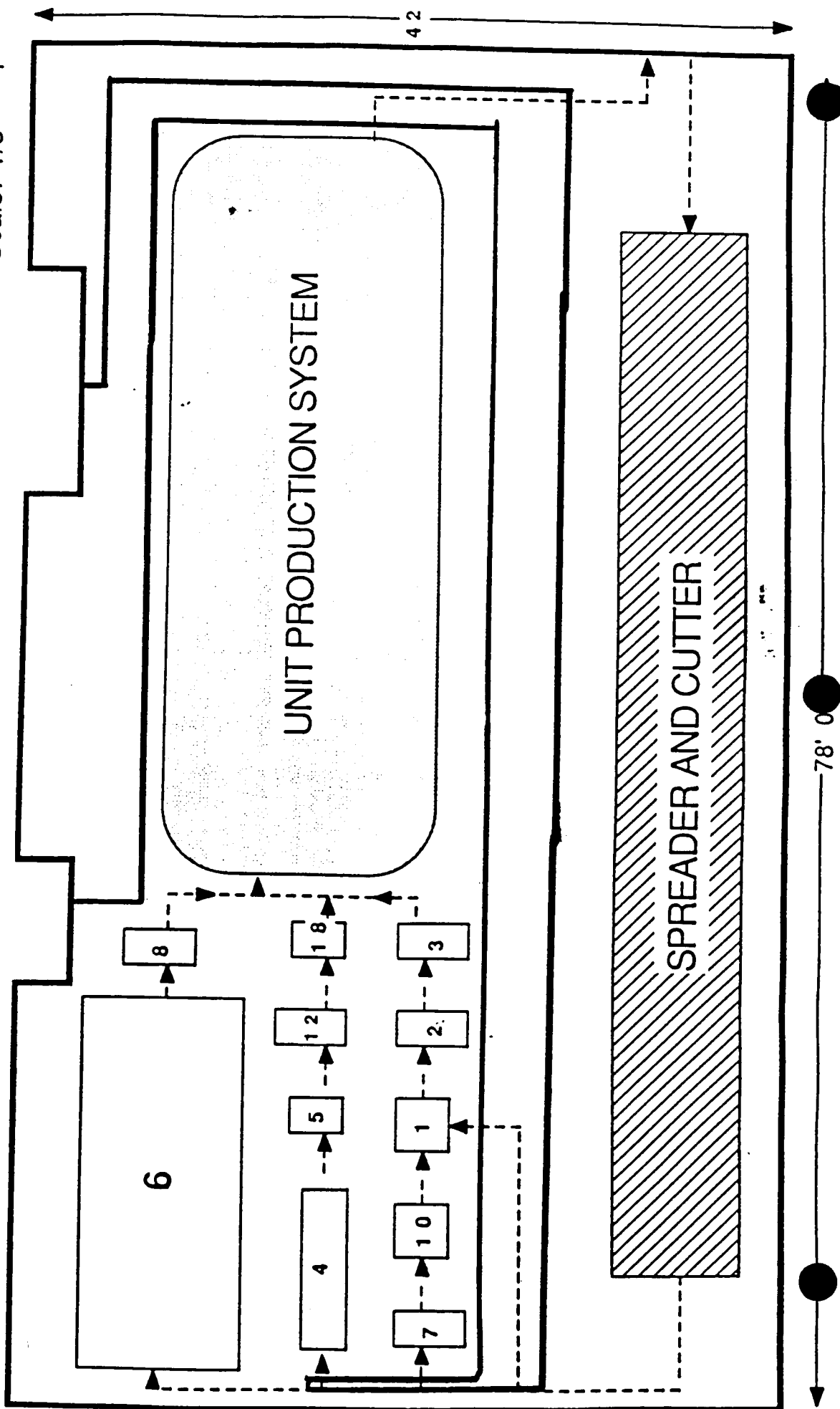
- i. During a demonstration, the observers will enter onto the manufacturing floor through doors leading from the hallway. (Highlighted in red on Figure 5) They will then turn left and walk along the the wall and down the six foot path to machine 6 and return along the same path. There is adequate space for the observers to leave this primary path, though, if they so desire.
- ii. This observer flow crosses the material flow pattern in one location: in transporting finished goods from the UPS to the storage area.

### 4. Aesthetics

- i. This layout does not allow the observers to see a significant amount of the production process from the hall. By limiting such viewing, the observers may not become initially interested in the demonstration.
- ii. The UPS blocks the view of cutter/spreader from hallway.
- iii. The aisle between the spreader/cutter keeps the processing area more open for observers to flow between machines.

# ALTERNATIVE 3

Scale: 1/8" = 1'



## G. Alternative Layout IV

### 1. Overview: Aisle at Windows/ Cutter in Back

- i. The front end of the spreader/cutter faces the doorway between the manufacturing area and the storage area. The rolls of raw material are transported from storage to cutter by a lift truck.
- ii. Same as Alternative I.
- iii. The bundles are separated into unit stacks; the unit stacks are loaded onto the UPS; the assembly and finishing processes are carried out.
- iv. The finished goods are carried from the UPS to the storage via a pallet jack or a buggy.

### 2. Material Routing

- i. This layout only contains complex material handling movements when moving raw materials from storage to the spreader/cutter via a lift truck.
- ii. Each process is adjacent to its successive process.

### 3. Observer Flow

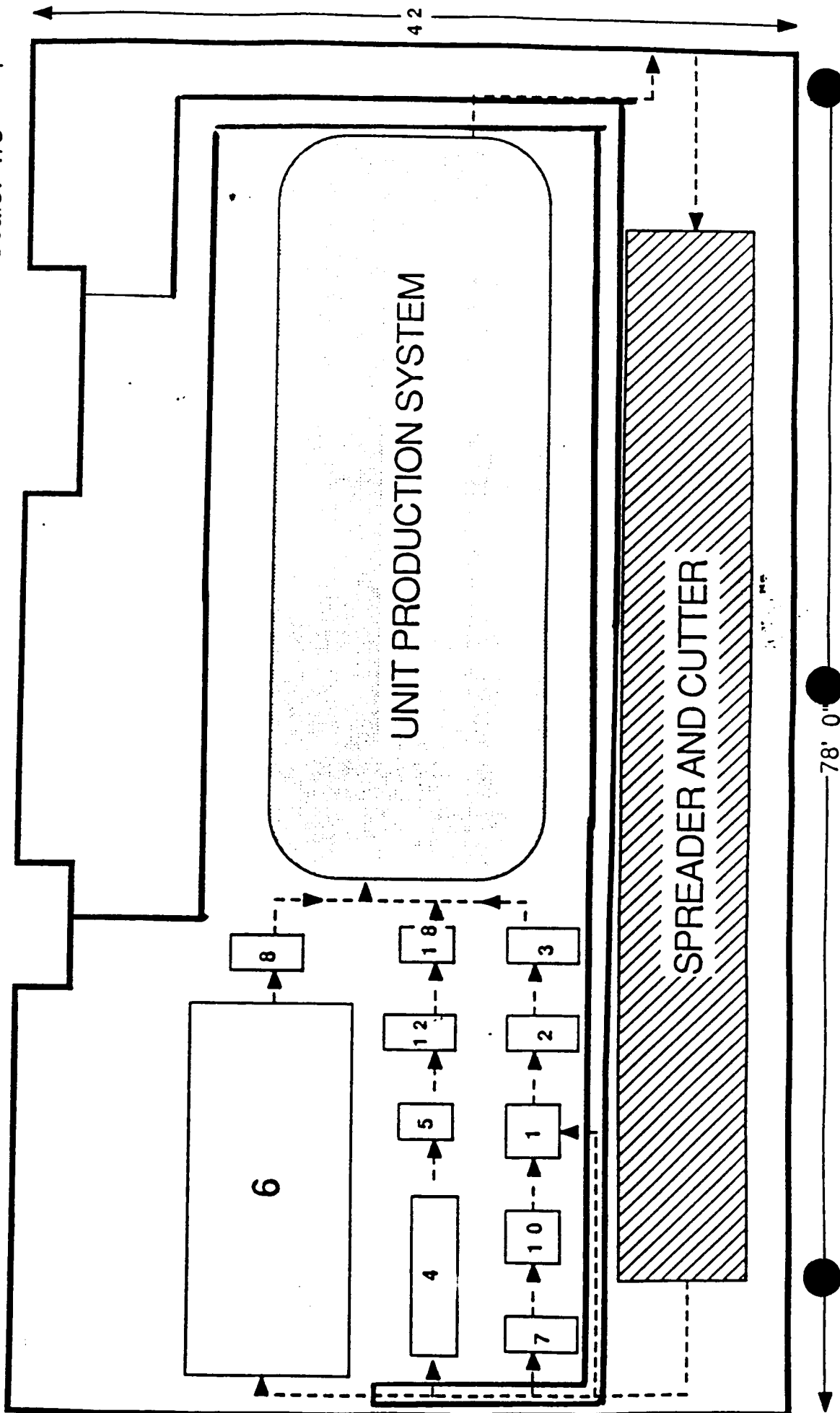
- i. During a demonstration, the observers will enter the manufacturing area through the double doors located on the glass wall. (Highlighted in red on Figure 6) They will turn left and travel along the wall until they reach the spreader/cutter. The observers will then walk beside the spreader/cutter until they reach machine 6. They can then view the subassembly machines and exit the room the way they entered.
- ii. This observer flow provides a primary path for the observers to follow that crosses the material flow pattern in one location: transporting of finished goods from the UPS to storage.

### 4. Aesthetics

- i. This layout does not allow the observers to see a significant amount of the production process from the hall. By limiting such viewing, the observers may not become initially interested in the demonstration.
- ii. The UPS blocks the view of cutter/spreader from hallway.

# ALTERNATIVE 4

Scale: 1/8" = 1'



- iii. Because there is no aisle between the spreader/cutter and the subassembly machines, the layout appears to be cluttered.

#### **F. Evaluation of Alternatives**

Subsequent to generating the alternatives, the following analysis was completed to determine how well the layouts meet the following criteria:

##### **a. Aesthetics**

- i. Viewability of layout by attendees
- ii. Routing areas available

##### **b. Material Flow**

- i. Ease of determination of material flow
- ii. limited backtracking

##### **c. Observer Flow**

- i. Accessibility of machines
- ii. Limited safety risks

Please note that costs will not be used as a limiting factor when evaluating the alternatives. However, good judgement was used to avoid unnecessary spending.

The evaluations were performed using both weighted averages and pairwise elimination. The results of these two evaluations are discussed on the next few pages.



# 1. Evaluation of Alternatives using Weighted Averages

<u>Aesthetics</u>	<u>Alt I</u>	<u>Alt II</u>	<u>Alt III</u>	<u>Alt IV</u>
-Able to see machines from window.	10	10	5	5
-Machines do not appear cluttered.	5	10	10	5
-Processing at each workstation can be seen from window.	5	5	5	5
-"Eyecatching" machinery located near window.	5	8	10	5
-Large levels of WIP shielded from viewers.	10	10	8	8
<u>Material Flow (30%)</u>				
-Flow is to consecutive workstation	10	10	10	10
-Materials follow the shortest path possible. (Rank 10-8-6-4)	10	8	6	8
-Flow is easy to follow.	7	10	10	10
-Room for material handling equipment	10	10	10	10
<u>Observer Flow (20%)</u>				
-Observer flow crosses material flow in a minimum number of places. (-2 for each crossing)	4	6	8	8
-Observers can mingle around machines. (-3 for each non-accessible side)	4	10	10	7
-Room for viewers to "group around" tour guide. (-5 for limited)	5	10	10	10

\* All workstations on the "backside" of the UPS cannot be seen from the windows.

### Calculations for Weighted Averages

Alternative I :  $.5(35.00) + .3(46.25) + .2(21.70) = 35.72$

Alternative II :  $.5(43.00) + .3(47.50) + .2(43.30) = 44.42$

Alternative III:  $.5(38.00) + .3(45.00) + .2(46.70) = 41.83$

Alternative IV :  $.5(26.00) + .3(47.50) + .2(41.70) = 35.60$

According to these calculations, Alternative II outranked the other three when using the designated criteria weightings. However, in order to insure that the most viable alternative was selected, the alternatives were also evaluated using pair-wise elimination.

## 2. Evaluation of Alternatives Using Pair-Wise Elimination

<u>Aesthetics</u>	<u>A</u> (I vs II)	<u>B</u> (A vs III)	<u>C</u> (B vs IV)
-Able to see machines from window.	II	II	II
-Machines do not appear cluttered.	II	II	II
-Processing at each workstation can be seen from window.	Same for all: I, II, III & IV		
-"Eyecatching" machinery located near window.	II	III	III
-Large levels of WIP shielded from viewers.	I	I	I
<u>Material Flow (30%)</u>			
-Flow is to consecutive workstations.	Same for all: I, II, III & IV		
-Materials follow the shortest path possible. (Rank 10-8-6-4)	I	I	I
-Flow is easy to follow.	II	III	III & IV
-Room for material handling equipment.	Same for all: I, II, III & IV		
<u>Observer Flow (20%)</u>			
-Observer flow crosses material flow in a minimum number of places.	II	III	III & IV
-Observers can mingle around machines.	II	II	II
-Room for viewers to "group around" tour guide.	II	II	II

Alternative II appears to be the best selection since it appears first in ranking in the criteria more than any other alternative.

### G. Selected Layout

According to our evaluations of the four alternatives, Alternative II ranks superior to the other three on the basis of overall aesthetic appeal, material routing efficiency, and ease of observer flow. Therefore, Alternative II will be deemed the "Demonstration Center" for the remainder of the report. Prior to continuing with reporting of miscellaneous information, the positive and negative aspects of this layout will be reiterated and means of overcoming layout deficiencies will be discussed.

1) Observers at the window will be able to see over the spreader/cutter and view most of the other processing machinery during a demonstration. It should be noted that the machines on the backside of the UPS will not be easily seen from the window. Therefore, since it is not necessary for machines to be in order on a UPS, the more "state-of-the-art" machinery should be located nearest the window

2) Workers should concentrate on keeping all Work-In-Process which is in queue for their workstation on the tables located behind them. (Table alternatives will be discussed under material handling suggestions.)

3) There is appropriate room for observers to mingle around the subassembly and assembly equipment. The strategic location of the six foot aisle also makes it

possible for viewers to group around the tour guide during the formal part of the demonstration.

4) Figure 7 illustrates both the material flow and the observer flow (in red). The material handling equipment, the amount of material in queue for each workstation, the table sizes and suggested location of the CAD/CAM room will be noted in the next portion of the report.

## H. Implementation Information

### 1. Material Handling Suggestions

Since no cost restraints were quoted for the AAMTDC, the demonstration center can either employ simple or complex material handling systems. However, it was stated to Group 11 several times that the purpose of the demonstration center is to show observers an example of integration of "state-of-the-art" processing machinery and techniques while maintaining high levels of aesthetic appeal. Therefore, Group 11 feels that the material handling should be kept simple to keep the room from appearing cluttered with extraneous equipment and to avoid diverting viewer's attention from the processing equipment. The simple material handling system being suggested is outlined below.

The need for a battery operated fork truck to transport the rolls of raw material from the storage area to the spreader/cutter is vital due to risks involved with people handling and orienting such heavy loads (over 400 pounds). Due to space restrictions, there was only room for a six foot aisle located along the route from the storage room to the spreader/cutter. Also, there was only room for a ten foot space between the front of the spreader/cutter and the wall. The least expensive, yet feasible, lift truck alternative found which could grasp the rolls from a pallet rack through the core and hoist it onto the

# DEMONSTRATION CENTER

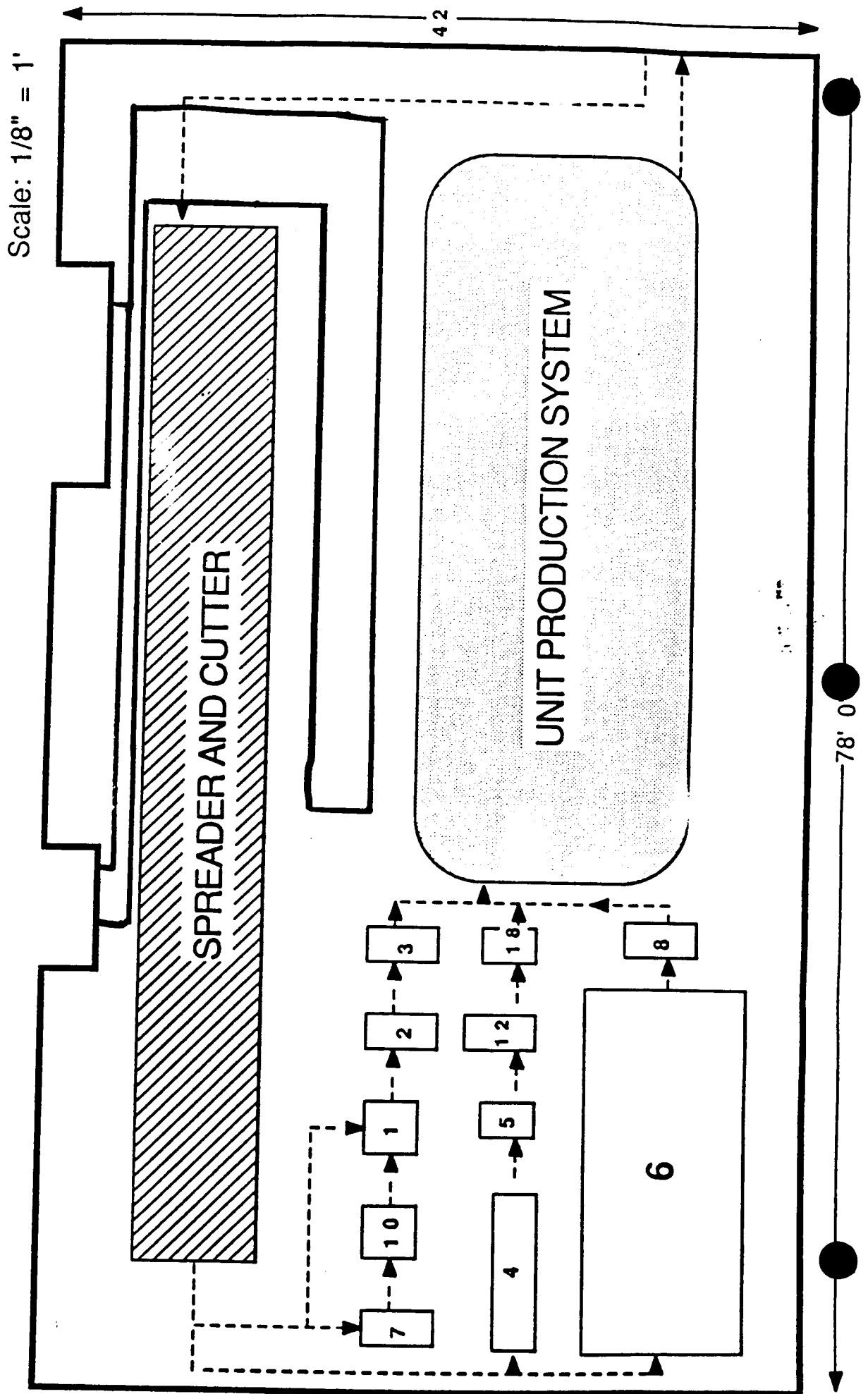


Figure 7

spreader/cutter costs approximately \$68,000--price based on 1985 figures with an 8% annual increase per year due to inflation and technological advances. This is a narrow aisle side loading lift truck with a grasping rod attachment. It requires a 5 foot aisle for forward travel and has a turning radius of 9 feet.

Four buggies can be located at the end of the spreader/cutter to transport materials from there to the subassembly area. The material would be deposited at the proper workstations and travel empty back to the spreader/cutter, ready to pick up another load of bundles.

Holding bins can be located between machines 3, 18, and 8 and the the UPS. These bins will be used to capture WIP waiting to be sent to the UPS sorting table. This area is too congested for buggies, and the bins would not take away from the room's aesthetic appeal.

Because of the fast processing times at workstations 2, 5, and 6, an "automatic elevating" bin or table can be located at each of these to hold their goods in queue. The table top will automatically lower as goods are stacked upon it, and it will rise as work-in-process is lifted from it. This will keep the materials on uniform levels for the workers and will prevent large queues from ruining the aesthetic appeal of the production room. Due to the recent discovery of this idea, exact price quotes are



unavailable at this time. However, Shelley Manufacturing Company in Miami, Florida is providing information on this type of equipment and its cost. This information will be evaluated and prices should be generated prior to May 30, 1988. If this evaluation does not prove possible, Senior Design Group 11 will be willing to put the AAMTDC administration in direct contact with a company representative. The rough estimate submitted is basically for a 2'x4' simulated wood table top with 2.5 ft high sides. It has an automatic lifting mechanism which can tolerate loads of up to 500 pounds and costs approximately \$407 per bin (\$370 plus 10% shipping and handling). Three bins would be needed for a total cost of approximately \$1200. This is a very rough estimate and should not be used as a basis for decisions before it is verified.

Finished jeans can be transported from the UPS to the storage area via buggies in order to avoid running the lift truck during demonstrations and risking possible accidents.

## 2. Location of CAD/CAM Room

The location of the CAD/CAM room could only be determined once the routing of center visitors had been discussed. Therefore, there are two main types of demonstrations which will occur at the AAMTDC:

- (1) Large scale demonstrations will occur biannually. At each of these demonstrations, techniques and typical production levels will be maintained for a reasonable duration to demonstrate the productivity of the equipment. Each year, one of these large scale demonstrations will occur during the Bobbin Show, at which time guided tours of the center and operational demonstrations will be performed for the public.
- (2) Quarterly, certain operations will be demonstrated on a scheduled basis. At this time, specific needs of the industry will be addressed as they are identified by the Defense Logistics Agency, equipment manufacturers, apparel manufacturers, and the Georgia Tech team investigating the nontraditional economic aspects of widespread implementation of advanced manufacturing technologies. The interim times between operations will be utilized for Research and Development activities and resolution of problems arising from producing military apparel.

At this point in time, only the routing for visitors attending the large scale biannual demonstrations at the AAMTDC have been explicitly determined. This routing would begin at the South entrance into the building (See Figure 8 for the tentative visitor routing(s) in red). The visitors would then proceed in the following manner:

- View a slide or film presentation in the AUDITORIUM (Area A)
- Have a break and informal questions/conversation in the RECEPTION AREA (Area B)
- At this point the visitors would have an understanding of the level of computer integrated manufacturing being achieved, so it would be strategically effective for the CAD/CAM room to be located so that viewers could easily look back and forth between it and the processing area. Since rooms 5, 6 and 2 are not available for the computer facilities, area 4 is the only viable alternative for their location.

### 3. Work-In-Process Levels

The following number of bundles should be located in queue for the designated workstations so that continuous processing can occur during an hour long demonstration. These number were generated using the Methods Time Motion time study technique for each processing machine.

<u>Machine #</u>	<u>Initial WIP</u>
1	0 bundles
2	4
3	0
4	0
5	6
6	10 (runs for only 20 min.)
7	0
8	0
10	0
12	0
18	0

This center will be able to produce four bundles (128 pairs) of blue jeans during an hour long demonstration.

#### IV. Full-Scale Facility

##### A. Scope of Design Project

###### 1. Boundaries of Project

The goal of the full-scale facility portion of the project was similar to that of the demonstration center. The final outcome was to be a layout for an apparel manufacturing facility. However, the full-scale layout was to consist of a balanced set of machines capable of producing 14,000 pairs of jeans a day. Therefore, the guidelines used to determine where the machines would be located were based on an analysis of production capacity, production flow, worker utilization, product flexibility, work-in-process levels, and cost. By using these particular criteria, group eleven hoped to develop an layout that would satisfy the needs of the sponsor as well as serve as a model for future layouts of other apparel manufacturing facilities.

###### 2. Constraints of Project

Several constraints had to be addressed in the design of the full-scale facility. These constraints included:

- a. The full-scale facility must have balanced production lines with a production capacity of 14,000 pairs of jeans per day.

b. The full-scale facility will run two, 8-hour shifts, utilizing the third shift for maintenance.

c. Space buffers of 4 ft. and 8 ft. are needed on the sides of each machine where buggy material handling systems are used.

### 3. Assumptions of Project

In developing the full-scale layout, several major assumptions were made. These assumptions included:

- a. Unlimited space was available for the layout.
- b. A UPS is applicable for apparel production.
- c. A UPS can be applied to the complete manufacturing process, not just assembly operations.
- d. The layouts generated entailed the design of the manufacturing process only.

### B. Approach Followed

The approach followed in finding a solution to the problem presented in the opening of the report was a combination of the scientific method and the "process of elimination" method. To obtain the desired results, the group realized either productivity must be increased or labor costs decreased or both. Being unfamiliar with the apparel industry, the group

attempted to study the present day methods to identify possible areas of improvement. It became obvious that American industry would not be able to compete with foreign markets in the category of labor costs. Therefore, the group concentrated its attention on the parts of the manufacturing process that could be automated, thereby cutting labor costs. The material handling system most commonly used today is a buggy-based one (unautomated). Having identified this section of the process as the one most likely to yield the results, the group proceeded to compare the buggy system with other systems. Finally, the group developed and evaluated alternative systems (both quantitatively and qualitatively) which could either replace or work in combination with the buggy system.

### C. Quantitative Evaluations

Three specific areas were used to quantitatively evaluate each alternative. These areas were purchase cost added, space cost, and work-in-process levels.

#### 1. Alternative Layout One - Buggy System

##### 1. Purchase cost added-

No cost was added by the design of a complete buggy system.

2. Space cost-

42,005 square feet x \$40 per sq. ft. = \$1,680,200

3. Work-in-process-

No savings were incurred with the design of a complete buggy system.



## 2. Alternative Layout Two - Unit Production System

### 1. Purchase cost added-

163 machines x \$4,000 per workstation = \$652,000

### 2. Space cost-

28,615 square feet x \$40 per sq. ft. = \$1,144,600

### 3. Work-in-process-

Alternative 2 involves a complete UPS system for the entire production process.

The industry average for material time buildup is 2 hours. The UPS system reduces the WIP time between machines to one hour.

The industry average for the amount of material on the manufacturing floor at any one time during production is four days worth of production.

Hence, there are 14,000 jeans per day x 4 days = 56,000 jeans on the floor at any one time.

Assumption: Of those jeans on the manufacturing floor, 50% are in the finished state and 50% are in material form.

Therefore, there are 28,000 jeans worth of material on the manufacturing floor.

The wholesale price can be assumed to be broken down as follows:

Materials	\$5.00
Labor	2.50
Overhead	<u>2.50</u>
	\$10.00

Therefore, there is  $28,000 \times \$5.00 = \$140,000$  worth of materials on the manufacturing floor at any one time. This material is idle.

If 100% of the plant is on the UPS, then there is a 50% reduction in WIP.

	w/o UPS	w/UPS
WIP	28,000	14,000
Finished goods		7,000
Material Inventory		7,000

This suggests  $7,000 \text{ jeans per day} \times \$5 \text{ per jean} = \$35,000$  per day not spent on raw materials.

Hence, the facility could utilize  $\$35,000 \text{ per day} \times 250 \text{ days per year} = \$8,750,000$  per year as an investment. This  $\$8,750,000$  can be calculated to a present value of  $\$7,954,625$  at 10% interest. Thus a  $\$795,375$  savings in interest results.

### 3. Alternative Layout Three - UPS with Buggy System

#### 1. Purchase cost added-

112 machines x \$4,000 per workstation = \$448,000

2. Space cost-

31,524 square feet x \$40 per sq. ft. = \$1,260,960

3. Work-in-process-

Alternative 3 involves a partial UPS system and buggy material handling system for the production process.

The industry average for material time buildup is 2 hours. The UPS system reduces the WIP time between machines 1 hour.

The industry average for the amount of material on the manufacturing floor at any one time during production is four days worth of production.

Hence, there 14,000 jeans per day x 4 days = 56,000 jeans on the floor at any one time.

Assumption: Of those jeans on the manufacturing floor, 50% are in the finished state and 50% are in material form.

Therefore, there are 28,000 jeans worth of material on the manufacturing floor.

The wholesale price can be assumed to be broken down as follows:

Materials	\$ 5.00
Labor	2.50
Overhead	<u>2.50</u>
	\$10.00

Therefore, there is  $28,000 \times \$5.00 = \$140,000$  worth of materials on the manufacturing floor at any one time. This material is idle.

If 70% of the plant is on the UPS, then there is a 37.5% reduction in total time:

	Non-UPS	UPS
70%	5.6 hrs	2.8 hrs
30%	<u>2.4</u>	<u>2.4</u>
	8.0 hrs	5.2 hrs

Therefore, there is a  $8 - 5.2 / 8 = 37.5\%$  reduction with UPS.

	w/o UPS	w/UPS
WIP	28,000	18,200
Finished goods		4,900
Material Inventory		4,900

This suggests  $4,900 \text{ jeans per day} \times \$5 \text{ per jean} = \$24,500$  per day not spent on raw materials.

Hence, the facility could utilize  $\$24,500$  per day  $\times$  250 days per year =  $\$6,125,000$  per year as an investment. This  $\$6,125,000$  can be calculated to a present value of  $\$5,568,238$  at 10% interest. Thus a  $\$556,763$  savings in interest results.

A summary of this analysis can be found in Figure 9.

#### **D. Qualitative Evaluation of Alternatives**

##### **1. Alternative One - Buggy System**

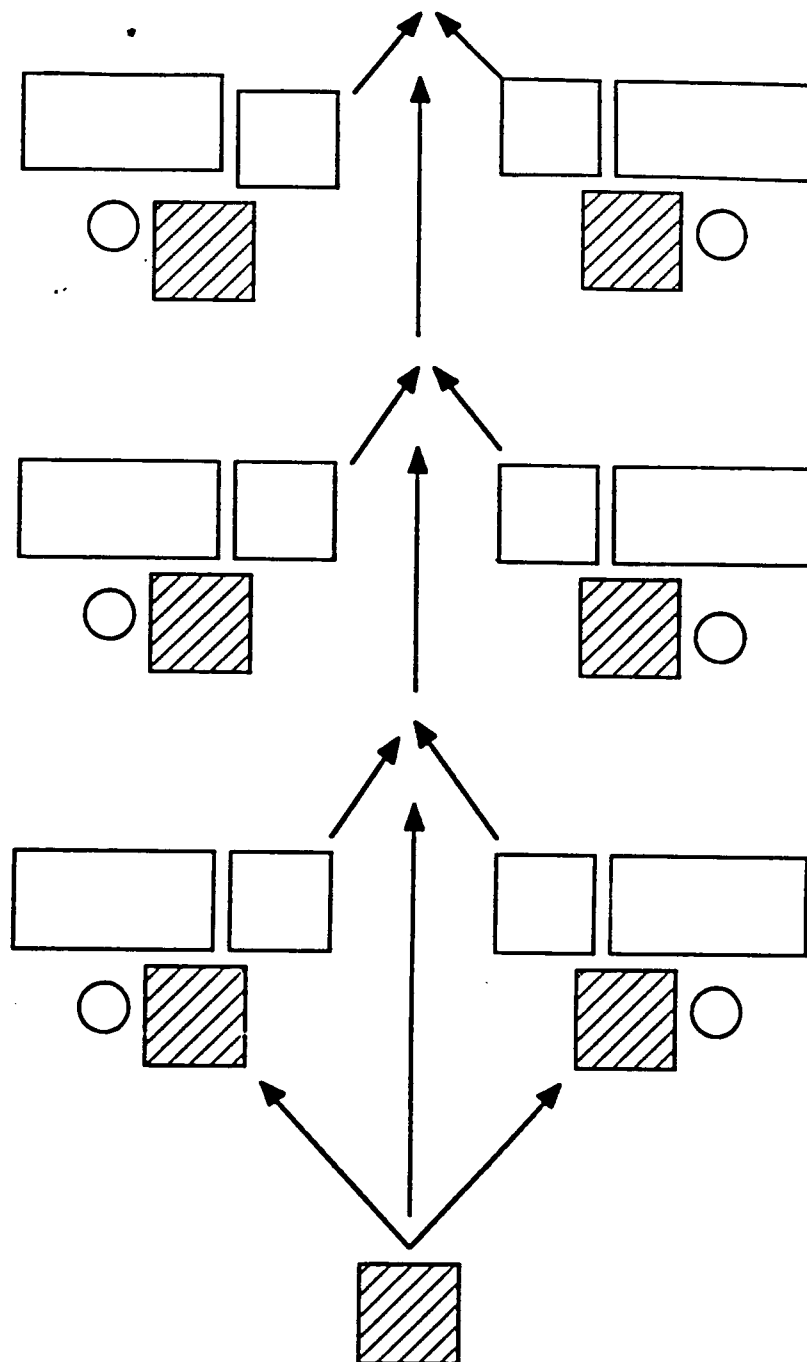
Early in the generation process of alternatives for the full-scale facility, Group 11 realized that the major potential for savings lay in the material handling system. The system that is currently being used in the majority of the apparel manufacturing plants, including the Lee Plant in Jasper, Georgia, is the buggy system (see fig. 10). This system has evolved throughout the years and has yet to be significantly supplanted by any other method for the production of unit batches of apparel. Senior Design Group 11 therefore decided to generate a version of the buggy system, modified to meet the particular needs of the client, as the first layout alternative (see figure 11).

After exiting the cutter, the parts are placed on buggies and wheeled to one of three subassembly lines. From there the pieces proceed down their respective lines and are placed with the other subassembly line's products to form a group with exactly enough pieces to make 36 pairs of jeans. These are then placed in a bag and sorted in the bin area. Here the bags are again placed on buggies and passed from one machine type to another type. At

## Quantitative Summary

	Alt. 1 (No UPS)	Alt. 2 (All UPS)	Alt. 3 (Partia UPS)
Purchase Cost Added	\$0	\$652,000	\$448,000
Space Cost	\$1,680,000	\$1,144,600	\$1,260,960
WIP Cost Reduction	\$0	(\$795,375)	(\$556,763)
Total Cost	\$1,680,200	\$1,001,225	\$1,152,197

# Buggy System



# **FULL SCALE FACILITY (ALTERNATIVE ONE)** **(BUGGY SYSTEM)**

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310°

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the end of the line the completed jeans are removed and the empty buggies are wheeled back to the starting bin area.

This material handling system is obviously effective as it is employed by most of the industry today. It also has the distinction of being the least expensive. However, it was conceived before the advent of the computer and therefore is possibly inferior in regard to the speed and accuracy now obtainable with a central processor. It is also very "space-heavy" and due to the amount of time the worker must spend passing buggies, it ranks very poorly in worker utilization and product flexibility. Also, a larger supply of WIP inventory must be maintained to allow for the production of 14,000 pairs of jeans a day. Based on these problems, and the quantitative analysis, the group rejected this design.

## 2. Alternative Two - Unit Production System

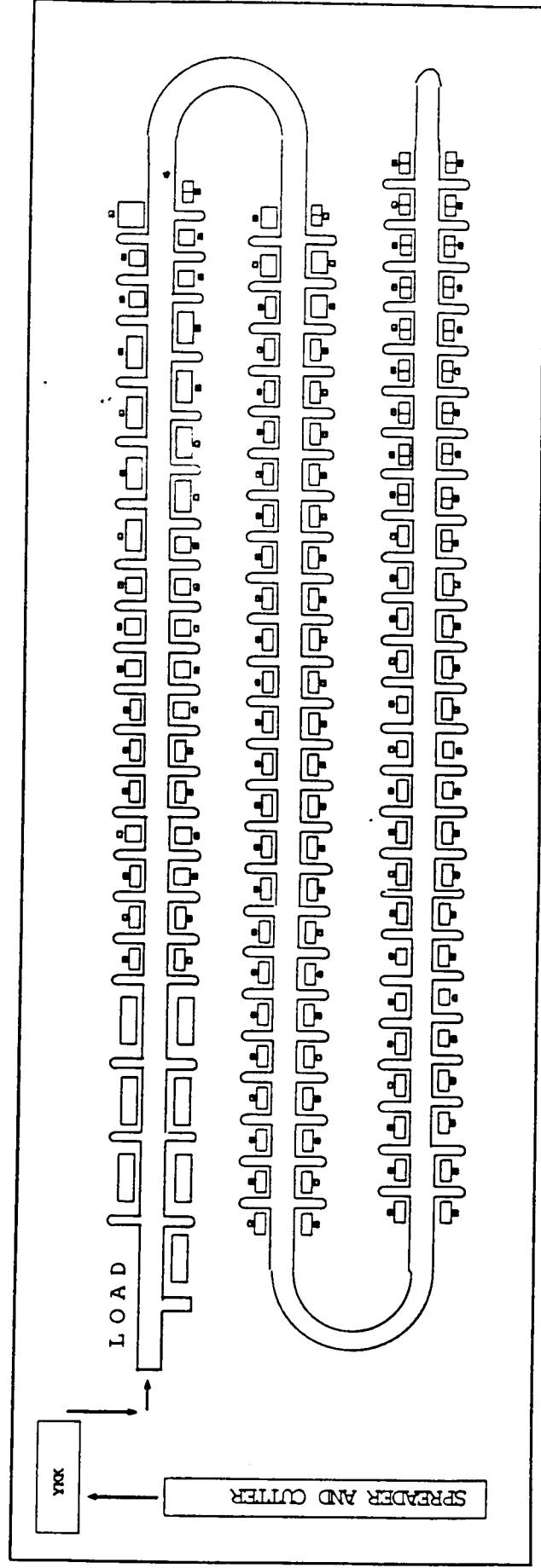
Another of the material handling systems that was investigated was the Unit Production System (UPS) (see fig. 15). This system uses a carousel concept (much like those used by dry cleaners) to transport WIP from workstation to workstation until the product is completely assembled. Due to the fact

that the system is transporting the WIP rather than the worker, a higher worker utilization can be obtained. Other virtues of the system include: less space needed, higher production flexibility and lower WIP levels. Because of these advantages, the group decided to investigate an alternative which utilizes a UPS for the entire production process (see fig. 12).

After the zippers are attached on the YKK machine, all remaining pieces of the garment are loaded onto the UPS machine. From here, the units are transported to one type of each machine until finally a completed garment is assembled. However, while this arrangement looks good in both the quantitative and qualitative sections, it is not practical due to the fact that any savings that may be obtained are more than outweighed by the excessive loading and moving times needed for the many small subassembly parts. Therefore, Group 11 rejected this alternative.

# FULL SCALE FACILITY (ALTERNATIVE TWO)

## (UNIT PRODUCTION SYSTEM)



### 3. Alternative Three - UPS with Buggy system

After generating two alternatives, one which utilizes a buggy-based material handling system and another that uses a unit production system, it became obvious that both systems contained traits which made them superior to the other depending on the manufacturing application. The UPS system can offer a decrease in space, work-in-process levels, and production time while increasing product flexibility and worker utilization. It is especially effective when the process contains large, cumbersome parts that tend to clog up buggy-based systems. The buggy system, which is currently used throughout the apparel industry, is an inexpensive, effective method of transporting parts from machine to machine. It proves superior for a process which has large number of small, easily handled parts and is more geared towards batch production.

The problem is that the process for making jeans does not fall clearly into either category. After the material is cut, several small pieces are "subassembled" (pockets tacked, zippers attached to flies, etc.) and then combined to create larger pieces. These larger pieces then continue on and eventually are joined (inseam, seatseam, sideseam)

to create a pair of jeans. Therefore, to develop an alternative which would allow for a more efficient production of 14,000 pairs of jeans per day, a material handling system which contained the characteristics of both the unit production and buggy-based systems must be developed. To do this, the design group decided to split the process into two parts: sub-assembly and assembly. This allows the client to use the buggy system in the sub-assembly (2-dimensional) portion of the process where the parts are small and numerous; and to use the UPS system in the assembly (3-dimensional) portion where there are less, but larger parts.

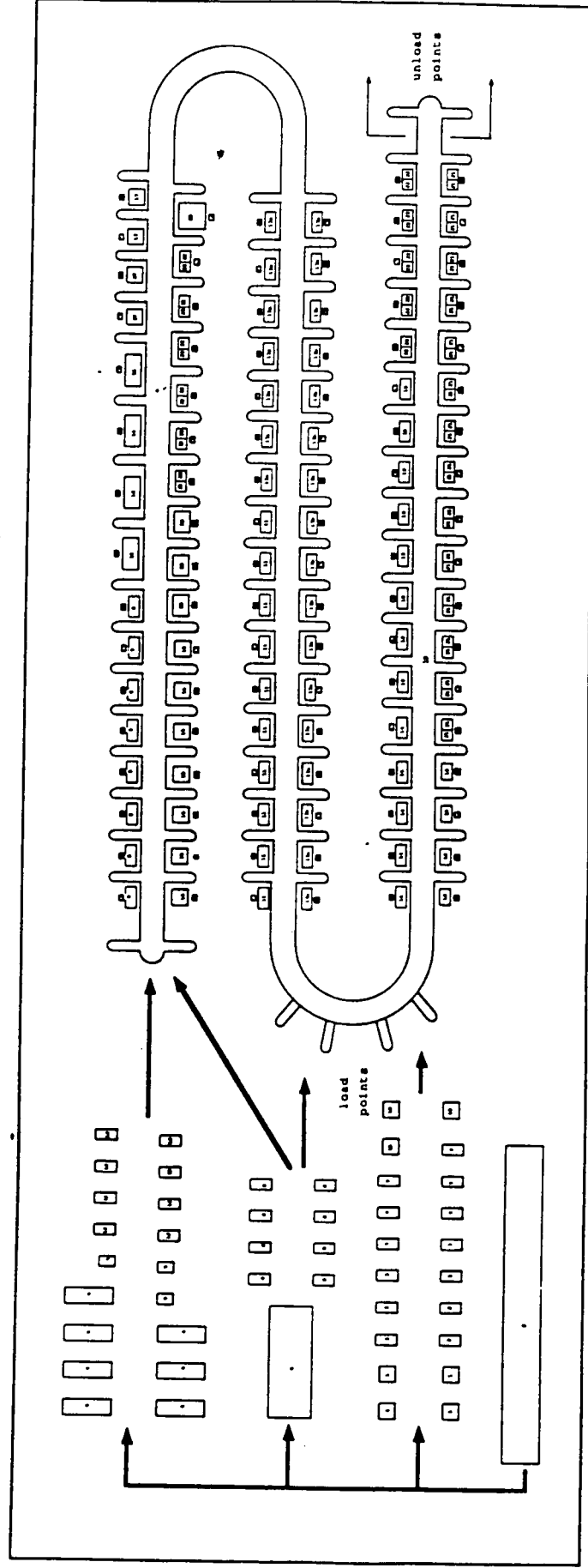
The resulting alternative (see fig. 13) was a result of several attempts to determine how many of the machines should be placed on the UPS and how many should be left on the buggy system. The final and best solution placed approximately 70% of the manufacturing machines on the new material handling system and left 30% on the buggy system.

After the parts come off the cutter, they are placed on buggies and carted to their respective sub-assembly lines. After exiting these lines, the resulting large parts are placed on the Unit Production System at one of the load points. The machines were placed on the UPS so as to minimize the distance from the preceding sub-assembly line

(see precedence diagram, fig 1). However, each pair of jeans visits each type of machine at least once before being taken off at the unloading point. A summary of the qualitative evaluation can be seen in figure 14.

# FULL SCALE FACILITY (ALTERNATIVE THREE)

## (UNIT PRODUCTION SYSTEM WITH BUGGY SYSTEM)



## Qualitative Summary

	Alt. 1 (No UPS)	Alt. 2 (All UPS)	Alt. 3 (Partia UPS)
Flexibility	-	+	+
Worker Utilization	0	+	+
Practicality	+	X	+

+ Excellent  
0 Satisfactory  
- Poor  
X Inpractical

Figure 14



## V. Time Spent on Report

On February 15, 1988 our sponsor requested that we estimate the hours to complete our project for the Apparel Advanced Manufacturing Demonstration Center. We are now finishing up our two quarter project so we can compare our estimates with our actual hours worked. The greatest error of estimation was in the category of Data Analysis. We spent over 700 hours on analysis alone in order to generate our results.

Here is the breakdown of hours spent on the 5 month project:

	<u>Estimation</u>	<u>Actual</u>	<u>% Error</u>
Meetings	500	650	30.0
Data Analysis	300	720	140.0
Report Generation	150	232	54.7
Presentation	60	56	6.7
Travel	50	45	10.0

Not only did we learn a great deal about facilities design, but we also discovered how difficult it can be to estimate hours to charge a client for our help. This project was not only a learning experience as far as designing a facility, but also in dealing with people as a consulting group.

# Unit Production System

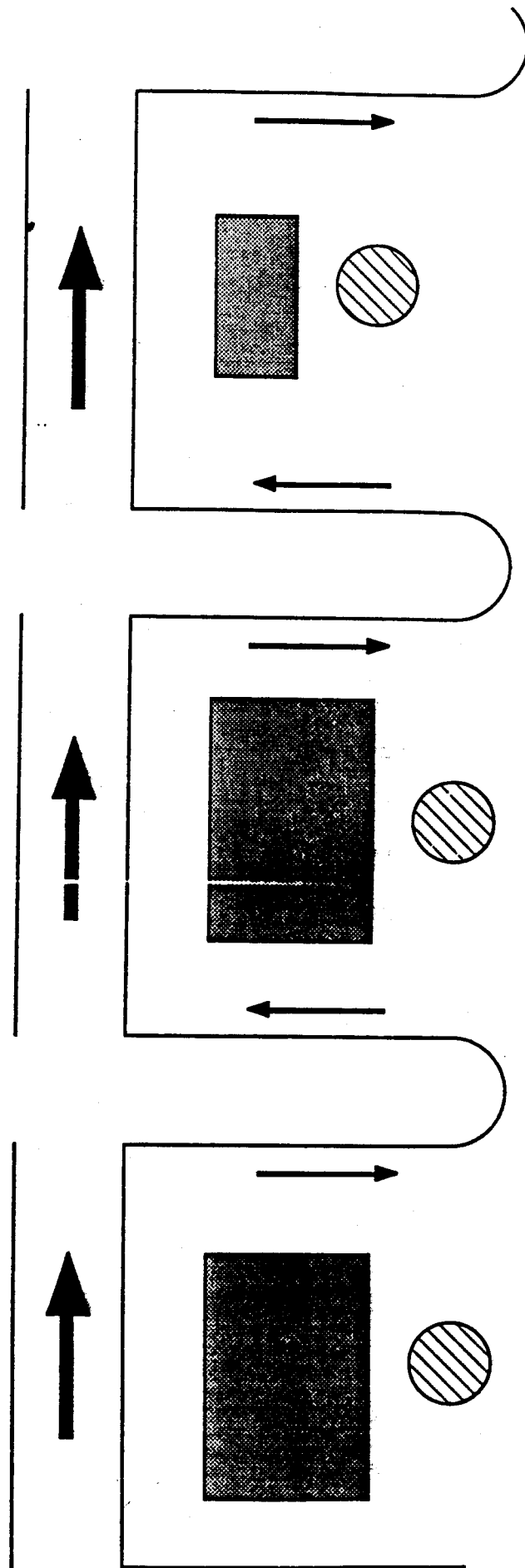


Figure 15

## VI. Conclusion

The driving force behind the AAMTDC construction is the inability of domestic apparel suppliers to provide garments in a timely manner at a reasonable cost of labor. Thus, the primary goal of the AAMTDC is to assist these apparel manufacturers in evaluating new manufacturing technology and adopting proven management techniques to improve their productivity. Therefore, Senior Design 11 welcomed the opportunity to design the production layout of the AAMTDC because of its potential significant impact on the American apparel industry. The project developed into two parts: the production layout design of the AAMTDC and the design of a full-scale facility which utilized all of the machines contained in the AAMTDC, but implemented them in full production. Senior Design Group 11 has certainly achieved this objective by producing both of these designs.

However, the project was not completed without setbacks. Most of the setbacks involved obtaining information needed by the group to complete the project. The sponsor was either unable to provide the information or a communication gap existed. A good example of this lack of information concerns the final selection of the machines that were to be placed in the AAMTDC. The information on these machines was promised to the group by February 11, 1988. However, the group did not receive the information until April 4, 1988 thus hindering the

natural design process and necessitated the elimination of some of the detailed analysis promised to the sponsor by the group.

Since the main focus of our project has been on the production layout design of the AAMTDC, the group has concentrated on the generation of layout alternatives for the AAMTDC and the analysis involved with selecting the best alternative. A lesser emphasis was placed on the full-scale facility since the sponsor identified the production layout of the AAMTDC to be critical. This report includes the selection of these final alternatives for the AAMTDC and the full-scale facility.

The implementation of the layout design, however, is subject to the actions of the AAMTDC administration. The administration may choose to implement the design or use it as a reference guide in determining a new layout. The main objective of the project was to provide a layout of the process manufacturing machinery under the constraints of the AAMTDC facility. Ultimately, this objective was achieved.

## Cost Estimation Calculations

The following is a cost tabulation of the machines that will be used by the AAMTDC and the full-scale facility:

Activity	Machine Name	Cost/Mach (thousands)	# Mach	Total Cost
0. Cut material	Gerber	\$229	1	\$229
1. Make back darts	Durkopp/MTM Dart Machine	35	4	140
2. Topstitch back darts	Mitsubishi 1240	12	3	36
3. Sew back label	" "	12	3	36
4. Hem front/back pockets	Pfaff	28	7	196
5. Buttonhole back pocket	Durkopp 558	4	3	12
6. Make left fly and attach zipper	YKK	10	1	10
7. Make and topstich right fly	Durkopp	6.5	5	32.5
8. Make and cord left fly	Pfaff	3.5	9	31.5
9. Topstitch and attach left fly	Union Special J-stitch	5.2	9	46.8
10. Serge right fly	Rimoldi	2.8	3	8.4
11. Attatch right fly and join front	Brother	3.3	9	29.7
12. Set front and back pockets	Pfaff	55	8	440
13a. Seatseam	Union Special	3.4	5	17.0
13b. Sideseam	Union Special	3.4	9	30.6
13c. Inseam	Union Special	3.4	7	23.8
+++++BEGIN THREE-DIMENSIONAL SEWING+++++				
14. Attach waistband	Pfaff and Atlanta attachment	26	5	130
15. Close band ends	JUKI	8	7	56

16. Buttonhole and button backpockets	Durkopp and Reese	4.5	4	18
17. Bartack fly and pockets	JUKI	3.6	4	14.4
18. Make belt loops	Pfaff	5.5	4	22
19. Attach belt loops	JUKI	22	8	176
20. Attach size tickets	Lewis ticket tacker	2.8	3	8.4
21. Press Garment	Vaporpress			
a. Jeans Machine		10	12	120
b. Utility Press		14.4	18	259.2
22. Inspection	Human	0.5	22	11
23. Clean garment	Cissel Steamtable	3.2	1	3.2
		-----		-----
Totals for each facility (in thousands)		\$517.0		\$2,137.5

**APPENDIX G**  
**Grants of Equipment and Services to AMTC**

## EQUIPMENT CONSIGNMENTS AND DONATIONS: 1988-1994

Vendor	Equipment	Catalogue Value (approx.)
Gerber	Pattern Plotter	\$33,000
Gerber	2 Digitizer Tables 2600-03	\$52,000
Gerber	Computer WY-3216-40	\$26,000
Gerber	Printer SP1200A1	Included Above
Gerber	Monitor WY-530-04	Included Above
Gerber	Monitor HM-46615-D	Included Above
Gerber	Keyboard 840358-13	Included Above
Gerber	Scanner Machine	\$10,000
Gerber	Copier Machine 4693D	\$11,000
Gerber	Color Video Camera TK087OU	\$3,500
Gerber	Monitor WY-530-04	Included Above
Gerber	Computer WY-3216-40	Included Above
Gerber	Keyboard	Included Above
	Printer	Included Above
Gerber	Creative Design	\$61,000
Gerber	Accumark System	\$80,000



**EQUIPMENT CONSIGNMENTS AND DONATIONS: 1988-1994  
(continued)**

Vendor	Equipment	Catalogue Value (approx.)
Gerber	UPS Console Terminal #17 Load Unit Prod Sys	#210,000
Gerber	#18 Overflow Work	Included Above
Gerber	#19 Sideseam	Included Above
Gerber	#20 Inseam	Included Above
Gerber	#7 Attach Waistband	Included Above
Gerber	#22 Finish band	Included Above
Gerber	#23 A&B Buttonhole Band & Buttonhole Band	Included Above
Gerber	#24 Attach Loops	Included Above
Gerber	#25 A&B Tack Fly & Sew Label	Included Above
Gerber	#26 Repair	Included Above
Gerber	#27 Unload & Fold	Included Above
Gerber	Computer 5154001	\$10,000
Gerber	Cutter System 91-93-95	\$260,000
Gerber	Spreader 12400	\$36,000
YKK	YKK-JALB2-7800 Machine	\$20,540
Durkopp	Durkopp 743-5-3	\$19,798
Durkopp	Durkopp 558	\$10,143
US	Union Special 35800DN	\$5,893
US	Union Special 35800BN	\$5,893

**EQUIPMENT CONSIGNMENTS AND DONATIONS: 1988-1994**  
**(continued)**

<b>VENDOR</b>	<b>EQUIPMENT</b>	<b>CATALOGUE VALUE (APPROX.)</b>
US	Union Special 2800E-4	\$14,440
Singer	Singer 2126141A	\$2,100
Singer	Singer 4696141A	\$3,100
Singer	Singer 275-E11	\$2,000
H.D. Lee	Singer 2124141X	\$2,100
Brother	Brother LK-3B495	\$45,000
Brother	Brother 2K3-B310	\$25,000
Lewis Sales	Mitsubishi PLK0804	\$10,225
Lewis Sales	Mitsubishi PLK1410	\$15,815
Lewis Sales	Mitsubishi LT2-250	\$6,300
Georgia Tech	Mitchell Robot	\$2,200
Reece	Reece 104	\$11,000
Pfaff	Wilcox Gibbs 504-E52	\$3,500
Juki	Juki MB-373	\$1,874
Juki	Juki 103-PC	\$21,671
Lee Co Pfaff	3518	\$56,000
Brother	B792	\$4,463
Juki	1152-4	\$14,000
Reece W Pkt	46003	\$42,000
Wilcox & Gibbs	515-4	\$4,800
Durkopp Adler	976-S-501	\$8,000
Union Special	63900	\$18,000

**EQUIPMENT CONSIGNMENTS AND DONATIONS: 1988-1994**  
**(continued)**

VENDOR	EQUIPMENT	CATALOGUE VALUE (APPROX.)
ACS	AS4000 Computer 30	\$110,000
ACS	Console 3179	\$1,482
ACS	Printer 0037018	\$12,345
Georgia Tech/ HP	Series 925 LX	\$623,000
Lewis Sales	Personal Computer 30 286	\$3,600
Dell	Five computer systems	\$24,000
Lewis Sales	Color Monitor	\$37,000
ACS	IPCS Software	\$40,000
Gunold	Software	\$105,000

## Firms Donating/Consigning Equipment or Materials to the AMTC

FIRM	AMOUNT
Apparel Computer Systems	\$163,845
Astechnologies, Inc.	3,000
Atlanta Attachments	24,000
Brother	70,000
Byte Systems	10,000
Coats & Clark, Inc.	1,160
Durkopp & Adler	190,000
EFKA	2,000
Gerber Garment Technology, Inc.	655,500
Gunold Ind.	105,000
Hewlett-Packard	623,000
Juki Industries of America	37,545
Kurt Salmon Associates, Inc.	40,000
Lewis Sales	35,600
Methods Workshop, Inc.	28,000
Mitsubishi Electric Sales of America	37,242
Mr. Engineer, Inc.	5,000
Personal Research Associates	500
Pfaff-Pegasus of USA, Inc.	64,400
Reece Corporation	72,000
Rimoldi	7,000
Singer Sewing Company	30,000
STAG, Inc.	11,000
Sunbrand/Barmish, Zeidel & Associates	21,000

Textile Clothing Technology Center	12,080
Ticket Pak	12,000
Union Special	26,000
YKK	20,540
Stone Mountain Handbags (copier)	2,000
Southern Tech	97,700
Georgia Tech	228,000
State of Georgia	2,500,000
Woodruff Foundation	700,000